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APOLLO MONTHLY PROGRESS REPORT

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Contract NAS 9-150

31 May 1962

CLASSIFICATION CHANGE

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NORTH AMERICAN AVIATION, INC.
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CONTENTS

~~CONFIDENTIAL~~

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CO[redacted]

~~CONFIDENTIAL~~

CO[redacted]

Page

[redacted]

Page

CO[redacted]

ILLUSTRATIONS

TABLES

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FLIGHT TECHNOLOGY

AERODYNAMICS

Launch Escape System (LES) Stability

Wind tunnel programs were completed to determine the effects of various configuration modifications on the LES static stability. An analysis of the results verified that improvements in stability characteristics after escape-rocket-motor burnout are obtained with a "flow separator" installed at the fairing over the rocket nozzles. Final configuration selection will be made upon completion of a dynamic analysis using the measured stability data of the flight characteristics.

Revision will be made to the launch escape system air loading and to the aerodynamic characteristics of the jettisoned tower configuration to account for the addition of the flow separator to the fairing of the escape motor nozzle.

Jet Effects Analysis

Preliminary estimates of the jet effects on LES stability characteristics have been completed. These studies relate the influence of the jet exhaust by effectively eliminating a percentage of the stabilizing interference wake between the rocket-motor case and the command module. The Mach number for each case is associated with the C-1 boost trajectory. The jet plume size increases with altitude; consequently, the jet effects become more destabilizing with increasing Mach numbers.

During the next report period, tests will be accomplished in which the escape motor jets will be simulated with solid plumes, and a preliminary analysis will be completed.

Jet Effects Test Program

A wind tunnel test program for determining the jet effects on LES stability has been formulated. The feasibility of simulating the escape motor jets with solid plumes has been established; model and test requirements have been determined; and a test is to be conducted in the Supersonic Aerophysics Laboratory tunnel.

A preliminary test program for the H_2O_2 hot-jet model in the Langley 16-foot transonic tunnel was established, and the preliminary design of the model was completed.

During the next report period, tests will be conducted over the Mach range from 0. 7 to 1. 3. Various nozzle cant angles and deflections will be investigated.

APOLLO WIND TUNNEL

High Reynolds number FS-2 tests on the launch escape system in the S&ID trisonic wind tunnel were completed (Table 1). The effects of several motor-shroud configurations, including variations in flow separator design, were investigated and were evaluated during tests (FS-2) conducted in the Ames unitary tunnel (Table 1). Data were obtained from Mach 0. 7 to 2. 4.

Preliminary dynamic-stability tests of the 0. 055-scale FD-2 model were completed at Langley. Dynamic-stability derivatives for the command module and for a preliminary launch escape system were obtained over the Mach range from 0. 70 to 1. 20. Three different centers of gravity were investigated for the command module.

Model design and fabrication were completed on the 0. 04-scale static-force model (FA-4) of the command module. This model will be tested in the hotshot II tunnel of the Arnold Engineering Development Center (AEDC) and will provide the first hypervelocity static-stability data for the entry configuration.

The 0. 045-scale PS-4 static-pressure model was completed and delivered to AEDC. This model will be tested in hotshot II for pressure distributions on the command module at hypervelocities.

The 0. 045-scale H-2 heat-transfer model of the command module, service module, and launch escape system was completed and delivered to AEDC. The model will be tested in tunnels B and C covering the Mach range of 3. 6 to 10. 0.

The first Apollo tests in the AEDC will begin during the next report period. Hypervelocity aerodynamic force and pressure tests will be conducted in hotshot II facility. Heat transfer tests will be conducted at Mach numbers up to 10. 0. The 0. 055 scale PSTL-1 pressure-distribution model of the Saturn-Apollo configuration will be completed. This model will provide air-loads data, including nonsteady buffeting pressures.

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Table 1. Model and Test Status, May 1962

Test Objective	Model Designation	Facility	Test Schedule	Status (as of 5/31/62)	Planned Status (as of 6/30/62)
STATIC STABILITY					
Conduct launch escape sub-system configuration studies using simplified models. Mach range 0.7 to 1.5 (SAL)	FS-1 (0.02 Scale)	NAA-SAL	6 to 16 April 24 to 17 April	Tabulated data report in writing, data plotting in work	Publish tabulated data report
Preliminary jet effects force data using an existing model modified to test in the presence of solid bodies designed to simulate the jet plumes at various altitudes. Mach range 0.7 to 3.3		NAA-SAL	11 to 22 June	Design completed and construction 80 percent complete, pretest effort about complete	Construction and tests completed
Conduct basic aerodynamic evaluation of the command module and LES design (Ames)	FS-2 (0.105 Scale)	Ames 8 by 7 ft	9 to 10 April	Tabulated data reports in writing, data plotting in work	Publish tabulated data reports
Determine high Reynolds number correlation data Mach range 0.7 to 2.6 (TWT)		NAA-TWT Ames 11 by 11 ft Ames 9 by 7 ft	23 to 30 April 10 to 14 May 15 to 17 May	Test completed	
		Ames 8 by 7 ft	25 to 29 May	Pretest effort begun	Test completed
Determine detailed effects of true simulaltion of escape motor jet exhaust impingement on command module, force and pressure data in the transonic Mach range	FSJ-1 (0.085 Scale)	LRC-16 ft Transonic	8 Oct. to 2 Nov.	Scale and design concept established and reviewed by LRC 16 ft WT staff. Detail design started on final model and for a preliminary calibration motor to be checked out approximately 3 Sept. 1962	Design 40 percent and construction 20 percent complete, pretest report in writing, evaluation of catalyst pack design and motor simulation capability
Conduct same basic design evaluation of the command module and LES configurations as FS-2 tests, but extend to the Mach range of 3.0 to 10.0	FS-3 (0.045 Scale)	AEDC-VKF-A AEDC-VKF-B AEDC-VKF-C	18 July to 3 Aug. 6 to 15 Aug. 20 to 14 Aug.	Detail design completed, construction approximately 30 percent complete	Complete construction, scheduled shipping date 5 July, publish pretest report, pretest conference 16 June
Measure aerodynamic force data at hypervelocities for the entry configurations (V = 10,000 fps)	FS-4 (0.040 Scale)	AEDC-VKF Hotshot II	18 to 29 June 5 to 16 Nov.	Model completed and shipped 25 May, pretest report published	Complete scheduled June test
Same as FS-4. Backup test using different impulse type tunnel and testing technique	FS-8 (0.050 Scale)	CAL 48 in. Shock Tunnel	25 to 29 June 10 to 14 Dec.	Purchase order placed, test date set	Pretest report published
Determine aerodynamic force data on the complete Apollo-Saturn launch configuration, Mach range - subsonic through M = 10.0	FSL-1 (0.020 Scale)	Ames 9 by 7 ft Ames 14 ft Ames 8 by 7 ft. AEDC-VKF-A AEDC-VKF-B AEDC-VKF-C NAA-TWT NAA-NACAL	20 to 24 Aug. 27 Aug. to 7 Sept. 10 to 14 Sept. 24 to 28 Sept. 1 to 5 Oct. 8 to 12 Oct. 5 to 9 Nov. 26 to 30 Nov.	Scale established and program discussed with all scheduled facilities, design 30 percent complete, construction 5 percent complete	Design 80 percent complete, fabrication 60 percent complete, pretest report for Ames test in writing

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Table 1. Model and Test Status, May 1962

Test Objective	Model Designation	Facility	Test Schedule	Status (as of 5/31/62)	Planned Status (as of 6/30/62)
		DYNAMIC STABILITY			
Determine dynamic stability of the command module in the entry attitude about both the symmetric and asymmetric c-g locations, Mach range 3.26 to 9.0, using the decaying oscillation technique	FD-1 (0.030 Scale)	JPL-20 in. JPL-21 in.	18 to 22 June 2 to 6 July	Models completed and delivered to JPL for dynamic balancing on air bearing	Complete scheduled June test
Determine dynamic stability of the command module and LES Mach ranges transonic and 1.5 to 4.6, using the forced oscillation technique	FD-2 (0.055 Scale)	LRC-8 ft Trans LRC-UPWT LRC-UPWT LRC-UPWT LRC-8 ft Transonic LRC-12 ft L.S.	7 to 11 May 28 May to 2 June 9 to 13 July 23 to 27 July 17 to 21 Sept. 1 to 5 Oct.	Revised tower to 120 in. length and returned model to LRC for 28 May LRC-UPWT test, tabulated data report published for March LRC-UPWT test	Tabulated data report published for May-LRC 8 ft transonic test
		STRUCTURAL DYNAMICS			
Investigate problems associated with buffeting on the SA-5 launch configuration at transonic speeds	SD-1 (0.08 Scale)	LRC 16 ft Transonic Dynamic	10 to 21 Sept.	Design 75 percent complete, construction 30 percent complete, magnetic shaker designed and in work, control equipment ordered, stiffness and mass distribution calculations complete, structural analysis report in work	Design 95 percent complete, construction 75 percent complete, calibration equipment design and construction started, pretest report in writing
		HEAT TRANSFER			
Determination of heat transfer rates for entry configuration, launch escape system, and hypersonic abort Mach range 6.0 to 9.0	H-1 (0.02 Scale)	JPL-21 in.	16 to 25 April	Data report 95 percent complete	Plotting of data in work, tabulated data report published
Determination of similar objectives to H-1 tests using a larger model that permits more detailed instrumentation, better Reynold's	H-2 (0.045 Scale)	AEDC-VKF-B AEDC-VKF-C LRC-UPWT	18 to 22 June 25 to 29 June 10 to 21 Sept	Design and construction complete, thermocouples 95 percent calibrated, pretest report	

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Table 1. Model and Test Status, May 1962

Test Objective	Model Designation	Facility	Test Schedule	Status (as of 5/31/62)	Planned Status (as of 6/30/62)
number simulation, and addition of service module Mach range 3.6 to 10.0				published, conference 29 May	
Determination of heat transfer rate for entry configuration at hypersonic Mach numbers. Mach range 12 to 20	H-4 (0.05 Scale)	CAL 48 in. Shock Tunnel	1 to 3 Aug.	Purchase order placed, test date set	Pretest report published
PRESSURE DISTRIBUTION					
Determination of pressure distributions on command module in the entry and launch escape attitudes using simplified models for early loads data. Mach range 1.5 to 9.0	PS-1 (0.02 Scale)	JPL-20 in. JPL-21 in.	12 to 16 March 2 to 14 April	Tabulated data report published for JPL-21 in. tests	Plotting of data in work
Determination of pressure distributions on the entry and hypersonic abort configurations using a larger model permitting more detailed instrumentation than PS-1, Mach range 5.7 and 10.0	PS-3 (0.045 Scale)	AEDC-VKF-A AEDC-VKF-B AEDC-VKF-C	30 July to 3 Aug. 13 to 17 Aug. 3 to 7 Sept.	Changed test facility (was Ames). Model redesign completed and submitted to vendors to bid on construction	Purchase order for construction placed with Mini-Craft Corp. on 4 June, scheduled completion for shipping to AEDC on 14 July, pretest report published, pretest conference 27 June
Determination of pressure distributions at hyper-velocities on the entry and hypersonic abort configurations (V = 10,000 fps)	PS-4 (0.040 Scale)	AEDC Hotshot II	2 to 20 July 19 to 30 Nov.	Construction completed and model shipped 30 May, pretest report published	Model set up and checked out ready for test at facility
Same as PS-4. Backup test using different type impulse tunnel and testing techniques	PS-5 (0.050 Scale)	CAL 48 in. Shock Tunnel	6 to 10 Aug. 17 to 21 Dec.	Purchase order placed, test date set	Pretest report published
Determination of steady-state and transient pressures on the Saturn-Apollo C-1 launch configuration	PSTL-1 (0.055 Scale)	NAA-TWT Ames-14 ft Ames-11 ft Ames 9 by 7 ft Ames 8 by 7 ft Ames-11 ft	18 to 29 June 6 to 17 Aug. 27 to 31 Aug. 10 to 21 Sept. 24 Sept. to 5 Oct. 19 to 23 Nov.	Design 100 percent completed, construction 90 percent completed, additional instrumentation ordered for obtaining test data requested by MSFC	Complete model and support June test in TWT, pretest report published, pretest conference 6 May

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FLIGHT DYNAMICS

Initial data for design and analysis of the stabilization and control system (SCS) were issued. These data included system requirements, weights and inertias, thrust characteristics, equations of motion and aerodynamic derivatives.

The recovery envelopes for deployment of the main chutes and the drogues with apex forward and heat shield forward were defined. Criteria established for off-design conditions defined the recovery envelopes.

Atmospheric abort criteria were established whereby pad abort is limited to one direction, and minimum pad-abort altitude is relaxed to 4000 feet. A simplified control system with limited authority is the primary objective.

A cross-range error-correction study was conducted in which the pilot's task was to realign the vehicle along its initial heading with a minimum of correction errors. Objectives were to assess the effect and to optimize the roll-rate limit combinations on lateral-correction capability and flight-path sensitivity.

During the next report period, definition of control requirements for the launch-escape system analog-digital studies will be continued to establish firm control requirements for control authority, nominal thrust alignment, and controlling parameter. The five-volume SCS data manual will be outlined, and available data will be inserted. Analog/digital studies will be continued using a prediction-guidance display. Objectives are to formulate maneuver logic and to determine trajectory characteristics of closed-loop, range-controlled entries. Drogue sequences and dynamic characteristics of the system will be studied using six-degree-of-freedom analyses of the parachute/command module combination.

AEROTHERMODYNAMICS

Aero Heating Analysis

Development of an analytical method of defining the flow field and corresponding heat-transfer distribution on the command module during entry has progressed with acquisition and evaluation of wind tunnel test data obtained at Jet Propulsion Laboratories (JPL). Using these data, it has been possible to calculate the velocity gradients existing on the model blunt face, thus providing a means of correlating an analysis with an experiment for determining wind tunnel test conditions. Effort has also been made to determine radiation heat transfer and ionization effects at flight conditions.

Heat loads were computed for a series of skip-out trajectories to determine the effect of trajectory on heat-shield weight.

Aerodynamic heating rates on the command module during a C-5 boost and a C-1 boilerplate test trajectory were computed. The effect of the launch escape tower has been estimated from the H-1 wind tunnel test program data.

A study was published concerning the aerodynamic reentry heating of the command module reaction control system (RCS) rockets.

A parametric study was conducted to determine possible locations in the command module aft equipment compartment for the RCS engines.

Aerodynamic heating rates on the service module and adapter were computed for a C-1 boost trajectory.

During the next report period, more extensive correlation of experimental results with analyses will be made for the Apollo configuration. As test results are obtained, this correlation will be extended to include data obtained in the "B" and "C" tunnel of AEDC. A more refined analysis will be made of the aerodynamic boost heating on the launch escape tower. Transition criterion will be established from experimental programs. Studies of the effect of trajectory on heat load will be continued to support the mission analysis required to establish the design criteria for the Apollo system.

Wind Tunnel Program

Testing of the H-1 heat transfer model at the JPL 21-inch hypersonic wind tunnel has been completed. Resultant data were gathered and partially reduced. Work was begun on the summary report for the H-1 tests in which aerodynamic heating predictions will be compared with test results.

Design specifications were completed for the heat transfer and pressure modules to be tested in the AEDC "B" and "C" tunnels. As a result of the JPL tests, the location of the thermocouples and pressure tops was revised to obtain a more precise location of the stagnation point.

A study is in progress to evaluate the basic concept of thin-skin heat-transfer models and to estimate heat losses due to conduction, convection, and radiation.

During the next report period, preparation for the AEDC and Cornell Aeronautical Laboratories shock tunnel tests will continue. The fabrication of models and the prediction of model heat transfers for test-data evaluation will be completed.

Construction has begun on the wind tunnel for aerodynamic heating tests on the command module reaction control system engines. A heat transfer program is now being written to aid in the reduction of data.

HEAT TRANSFER ANALYSIS

Command Module

An evaluation of ablative material and insulation requirements for the command module is being performed for the design trajectories. Test samples are being prepared to determine the material properties needed for the analysis of ablation processes. This test program will also determine the chemical reactions that will occur during ablation, the static thermal properties, and the dynamic thermal properties.

The time-temperature history of the cabin wall of the command module during a pressure failure has been completed. This was done for translunar, lunar-night, and lunar-subsolar operation.

A study was made to determine the thermal environment surrounding the battery compartment in the command module. The lunar-stay conditions are more severe than the translunar, earth, and lunar orbits.

During the next report period, initial plasma-jet testing of ablative materials will be initiated. Thermal-property measurements of ablative materials, honeycomb sandwich panels, insulation materials, and structural members will be taken as required. Boost-heating and impingement-heating studies of the boilerplate structure of the command module are being initiated. Studies will be initiated on RCS rocket boost-heating effects and impingement, in-space temperatures of command module components, reentry heating effects on command module components, and post-parachute deployment and post-landing of command module components. A study of the parachute compartment will also be initiated.

Service Module

A study of the aluminum-honeycomb shell structure of the service module during boost heating has been completed.

Results of a heat-transfer study show that maximum face temperatures of 288 F and 337 F are expected for face thicknesses of 0.030-inches and 0.023-inches respectively during boost of the aluminum-honeycomb adapter of the service module.

The heat-transfer network system, developed for the analysis of the temperature of service module components during an earth-moon flight, will be extended during the next report period to include lunar-orbit, lunar-landing (both day and night) and moon-earth-return flights. The analysis will be amplified for a three-dimensional model.

Launch Escape System (LES)

A preliminary boost-heating study was made of the LES nose cone, tower-jettison motor, rocket casing, and skirt.

The amount of ablative material required to provide adequate thermal protection for the support structure of the LES has been estimated for a sample case using a round tube normal to the direction of flow. Because of a lack of useful data relative to the performance of ablative materials in the exhaust stream of solid propellant rockets, a materials test program was initiated.

During the next report period, a test program will be started to determine the effect on ablative materials as result of exhaust impingement from solid-propellant engines. An initial set of 12 tests is to be conducted at McGregor, Texas, to obtain data for selection of the ablative material and material requirements for the LES support structure.

Further studies will be undertaken of the launch escape system during boost.

ENVIRONMENT CONTROL SYSTEMS (ECS) ANALYSIS

Equipment Cooling Systems Analysis

A network was devised for coolant flow through the lower equipment bay electronic-cooling system coldplates.

A test coldplate is now being fabricated from a design based on preliminary analysis. A computer analysis of the test plate is being conducted using various heat-input rates and coolant temperature differentials to establish test parameters. Test results will be used to verify assumptions made in the analytical programs. Resulting test and analytical data will provide an accurate method of predicting the performance of various sizes of coldplates.

Interface conductance tests were run on aluminum samples having various finishes and degrees of flatness at ambient pressure and in a vacuum of about 10^{-5} mm Hg.

During the next report period, an electronic cooling system analysis is scheduled as part of an integrated program that will simultaneously solve pressure drop, flow, and temperature distribution.

As materials become available, further interface-conductance tests will be run using interface filler materials applicable to the coldplates. A typical coldplate will be tested to verify analysis parameters and assumptions.

Noxious Gas Removal

Compilation of a list of command module materials to selectively classify potentially toxic properties was begun. These materials are being investigated to determine the following:

1. Location (with regard to possible venting of gases)

2. Fire resistance

3. Exposure to excessive temperatures

4. Gases resulting from thermal decomposition

5. Toxicity of gases released for normal and material-failure conditions.

A complete investigation of every material is not feasible. However, various materials can be grouped with particular regard to chemical constituency and quantity of gases released. A study is being conducted of ECS capability with regard to contaminant control.

During the next report period, the investigation of trace contaminants resulting from command module materials and their interactions will be continued. A study of the compatibility of the ECS with trace contaminants will be continued.

Crew Support Systems Analysis

A preliminary analysis was made of the waste-management and crew-support systems to determine the vacuum-cleaner flow rates, pressure drop, and associated line sizes for a lunar-landing mission.

Two analyses were made of urine management: the effect of humidity load and atmospheric contamination of the command module, and daily evacuation of urine to the vacuum of space without freeze-up. It was

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concluded that humidity load and atmospheric contamination would be negligible and that freeze-up could be prevented by a proper orificing of the evacuation line.

A study of feces storage indicates that gas build-up due to anaerobic decomposition will be a problem. This will effect storage space and bag rupture during cabin decompression.

The testing of personnel in pressure suits was started. These tests are to determine ventilation flow rates as well as latent and sensible heat loads.

Environmental Control System (ECS)

A study was completed to define the decompression rates of the command module for various hole sizes with the environmental control systems functioning.

A computer program was written for the suit circuit. It is complete except for minor debugging and replacing some of the assumed flow characteristics of components. This program will be expanded to include the cabin temperature-control system and the liquid-coolant loop. It will be used to analyze system performance under the various planned mission modes.

With the exception of the telemetry system, no environmental criteria information has been received from NASA for the rest of the instrumentation and communication equipment which is scheduled to go into boilerplate 6 or into a subsequent boilerplate.

The addition of a stability and control system for thrust vector control (TVC) of the launch escape motor has added no new ECS requirements to boilerplate 6.

A series of preliminary temperature profile curves has been completed for boilerplate 6. They cover the on-pad, count-down, and close-out period temperature ranges at the probable test-site location. These profile curves indicate that ground cooling will be required for pad operation.

During the next report period, studies will be conducted to define the equipment-cooling concepts for boilerplate 13 and 15. These are orbital flights; therefore, the system concept will differ from the one for boilerplate 6, 12, 20, and 21.

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Nuclear Radiation Shielding

A study was completed of the anisotropic component of solar-proton events. Results indicate that some events are directional in part, and thus shadow shielding may be of use during part of the lunar mission.

A study is being conducted into the probability of encountering solar-proton events. The period chosen for this analysis is a 30-month period, from July 1967 to December 1969 and from July 1968 to December 1970. This period will be assumed to be similar in solar activity to the period from July 1957 to December 1959.

A preliminary study is being conducted to determine the type of instrumentation and the amount of space-radiation information that could be obtained from early boilerplate flights.

During the next report period, the instrumentation studies for the boilerplate vehicles and the effect of proton flux below 100 Mev will be continued.

POWER SYSTEMS ANALYSIS

Cryogenics Storage Subsystems

The design criteria for the supercritical gas storage system were determined for the 14-day mission, which includes a subsolar lunar stay. This was for a nominal 7 psia cabin pressure with 50-percent nitrogen and 50-percent oxygen. A study is now under way on a 5 psia pressure system with 100-percent oxygen. The procurement specification for the supercritical storage system was released to a selected group of bidders.

The computer programs are presently under development. The first program is to obtain supercritical storage temperatures and pressures versus mission time; the second is to determine tank size including the insulation dimensions.

During the next report period, additional computer programs will be developed to define all of the performance processes of the cryogenic storage systems as well as the pertinent design parameters. A study of the storage systems using one tank for each gas rather than two will be initiated. The existing system will be modified. This modification will reflect the new metabolic requirements as well as the latest ECS requirement changes.

Fuel Cell Power Subsystem

The fuel cell and its auxiliary thermodynamic control systems are being analyzed from the standpoint of sensitivity to load and temperature changes. Thermodynamic relationships have been derived describing the various processes that occur during operation.

During the next report period, relationships will be written describing thermodynamic control including the following:

1. Primary-to-secondary condenser

2. Primary regenerator

3. Water separator

4. Reactants preheaters

The degree of fuel cell control will be estimated on the basis of load change and parameter variation of the control components.

Space Radiators

The computer programs used in conjunction with the analyses of the heat rejection requirements for ECS and electrical power systems (EPS) were refined for a more accurate determination of radiator requirements.

To permit investigation of system processes during "off-design" conditions, the sizing program was revised to accommodate radiator dimensions, heat load, and the fluid flow rate as input data. The fluid inlet and outlet temperatures, heat-transfer coefficient, and system pressure drop will be computed by the program.

An auxiliary computer program is being employed to obtain data required for the orbiting and cislunar phases of the mission. This program utilizes surface geometry and properties, vehicle attitude, and orbit altitude as input data to determine the surface equilibrium temperature and absorbed thermal radiation as a function of orbit time.

A test program was initiated to determine the realistic properties of radiator surface coatings.

A design review presentation on space radiators was made to NASA. This agenda outlined space radiator configuration studies and test programs.

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The basic design criteria for ECS heat rejection was established and was employed to generate the preliminary space radiator configuration.

An evaluation of surface property effects was made to determine if the use of coatings with less optimistic values for absorptivity and emissivity could be accommodated by employing supplemental cooling water.

The EPS radiator was sized for a 14-day, lunar-landing mission.

A study was made of the integrated heat rejection system for the ECS and the EPS with operational capabilities for lunar night and day. Though more reliable than the nonintegrated system, it was heavier in weight with the same capabilities.

The analysis of the heat rejection requirements for the ECS and EPS will be continued and new and changed parameters will be employed as they become available.

PROPULSION SYSTEMS ANALYSIS

Rocket Engine Systems

The heating of the command module reaction control system (RCS) thrust chambers during reentry (undershoot trajectory) has been evaluated.

Cooling of the thrust chamber and the nozzle was analyzed by coolant injection and by low-thrust combustion operation of the engine. The weight penalty and system complexity exceed the ablative engines.

It has been recommended that the Marquardt engine design be redirected in favor of an ablative-type thrust chamber. An ablative thrust chamber appears to have the characteristics that can withstand the thermal environments to which it would be subjected during reentry of the command module.

During the next report period, studies of throttleable engines for Apollo spacecraft applications will be continued. The service propulsion system optimization study will continue in order to determine in detail the trade-offs of various chamber pressures and nozzle expansion ratios at thrust levels that may be used in future Apollo missions.

Propellant Feed Systems

A preliminary IBM program (3JA2) for helium-pressurization system thermodynamic analysis has been checked out and is now in production. This program, which is being used for the preliminary analysis and optimization of service propulsion systems, computes time-step thermodynamic conditions for the helium remaining in the bottle and for that which is transferred to the propellant tanks. A more sophisticated computer program for the analysis of propellant systems is being developed.

Analysis indicates that the ullage temperature in the service-propulsion propellant tanks will be approximately 60 F below the propellant temperature on shut-down after 280 seconds of firing. Subsequent warming of the ullage and vaporization of the propellant can increase the ullage pressure to a value above the tank-design pressure of 240 psia.

Separate analyses were completed for propellant-storage tank pressures at conditions on the launch pad, in transit, and on the lunar surfaces. These analyses were made for the service module main-propulsion system, and for the service module and command module reaction-control systems.

Tank pressure has been determined for any propellant weight, as a function, during the initial and final conditions.

Pressure-drop analyses of the alternate-flow systems currently being proposed for the service module main-propulsion system were completed. On the basis of these analyses, recommendations for the line size of the propellant-feed system is 2.5 inches for the fuel system and 3.25 inches for the oxidizer system. Line-pressure drop is calculated to be 3 psi.

Zero-gravity environment will have significant effects upon fluid-flow and heat-transfer processes and will particularly affect engine restart capabilities.

During the next report period, a revision is planned that would enable the preliminary IBM program to prescribe heat addition to the pressurant. An analysis and optimization will be made of the helium-pressurization system for the command and service module reaction-control system. A test program will be prepared to evaluate propellant-system problem areas arising from a zero-gravity environment.

Interface Systems

The plume analysis performed during this period indicates the necessity of either thermally protecting the service module from the exhaust plume of the service-module and reaction-control-system motors or isolating the plume from the surface.

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A study was initiated that will culminate in a program for testing the service module and reaction-control system motors at simulated space pressures. The test will also provide data for correlation with the existing analytical methods of predicting the plume characteristics in space pressures.

The IBM programing of an approximate method of predicting plume-flow parameters is in progress.

During the next report period, a computer program is planned for an exhaust plume analysis by the method of characteristics. The exhaust-plume effects of the escale rockets on the support structure and the command module at altitudes from sea level to maximum escape altitude will be determined.

GSE Support

An analysis of line-pressure drop and pressure drop in the fittings of the GSE fill system was completed for both the fuel and the oxidizer systems of the service module main-propulsion system.

During the next report period, an evaluation will be made of total GSE fill-pressure requirements as a function of propellant fill temperature and propellant-tank pressure required after fill, fill flow rate, and line size.

LUNAR LANDING MISSION

Reliability Interface

A discussion was held to clarify reliability goals and apportionments between guidance and navigation, stabilization and control systems (SCS), and TVC subsystems. Basic relationships between subsystem reliability and mission success to crew safety were investigated. The effects of degraded performance in conjunction with back-up modes were considered.

Results indicated current reliability philosophies to be reasonable. For expediency, the exercises did not consider all conceivable back-up modes or the potential recovery region in cases of back-up mode operations. Future studies will include both of these areas, as well as general-abort philosophies and their relation to trajectories and performance.

Terminal Range Control

A closed-form steering scheme for longitudinal range-control during entry has been derived and included in the trajectory program. Lateral-range control logic and finite-roll rates are presently being included in the program.

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Entry Design Trajectories

Design trajectories for loads and heat-shield analyses have been revised. With regard to heat-shield design, the revised trajectories reflect the following major changes:

1. Forty-three percent increase in maximum heating load (stagnation points)

2. Elimination of the supercircular 20 g load factor as a design objective

3. Inclusion of a maximum-time skip-out trajectory coincident with a 10 g reentry

Ballistic Entry from Lunar Missions

A feasibility study was completed on the ballistic (zero-lift) entry maneuver as a possible emergency flight mode for lunar entries. Based upon single-pass and 12 g maximum load-factor criteria, the guidance corridor is 9 nautical miles. When atmospheric-density deviations are considered (±50 percent from standard), the allowable corridor is reduced to 4 nautical miles. Touchdown dispersions within the defined corridor exceed 2500 nautical miles.

Apollo Parachute Recovery Envelope

A revision of the recovery-initiation envelope was affected. The major deviations from the previous envelope are an increase in the upper Mach number limit to M = 0.7 at the 40,000-feet level.

Measurement Requirements for SA 5 and SA 6 Flights

Flight technology measurement requirements for SA 5 and SA 6 flights were determined. These represent requirements from aerodynamics, flight dynamics, trajectories, and performance.

Lunar Geometry Parameters

The nodal position of the lunar equator and the lunar-orbit plane was determined in selenographic coordinates as function-of-Julian data. These data will link generalized trajectory parameters with ephemeris data permitting the determination of propulsion requirements for the lunar-orbit and the lunar-landing missions.

Precision Trajectory Program

A special triaxial-moon adaptation of an Encke precision trajectory program was completed to provide a tool for lunar-orbital stability studies. Cathode-ray-tube data output was added to provide time-history plots of the orbital parameters.

Trajectory Search Routines

A linked conic trajectory program with an ephemeris look-up was written by modifying an existing Encke precision trajectory program. This simplified program will be used to obtain initial conditions for precision trajectory analyses.

Little Joe II Maximum "Q" Test Performance

It was determined that the Little Joe II launch vehicle configuration will require three Algol motors and four Recruit motors to perform the maximum "Q" abort test. This performance is based on latest S&ID drag-and-payload-weight estimates. For liftoff, four Recuits and two Algols will be simultaneously ignited. The third Algol will be ignited 11 seconds after liftoff.

Service Module Performance and Payload Tradeoff Studies

With reference to the major Apollo lunar-landing concept redirection, parametric studies were completed that present service module performance versus lunar excursion module payload. For a translunar injected weight of 82,500 pounds including a lunar excursion module of 20,000 pounds, the service module can accommodate a maximum usable-propellant load of 39,500 pounds.

Saturn C-1 Plus Service Module for Orbit Injection (Apollo "A" Mission)

Based upon the command module and service module weights designed for the lunar excursion module mission, the earth-orbital payload capability on Saturn C-1 was computed by using the service module for orbit injection. The nominal weight into orbit at 100 nautical miles is approximately 24,000 pounds. The propellant remaining in the service module, for orbital maneuvering and retro, is equivalent to a characteristic velocity of 2030 feet per second. This limits the maximum orbital altitude to 265 nautical miles since a characteristic velocity of 575 feet per second is needed to transfer from 100 nautical miles to 265 nautical miles and an additional 1455 feet per second is required for orbital retro and recovery from this altitude.

Digital Program Development

The following programs have been written and checked out on the IBM 7090 computer:

1. By means of a Newtonian flow field, equations for the static and dynamic hypersonic-aerodynamic coefficients were solved for a body of revolution with an offset center of gravity, and the results were plotted on an IBM cathode ray tube.

2. The trajectory of a multistage vehicle over a rotating spherical or oblate earth was determined. The program is three dimensional and includes gravitational, thrust, and aerodynamic effects.

3. The influence of inertial-sensing component tolerances on the accuracy of trajectory parameter was determined. Data generated by this program will be used to investigate guidance-performance interfaces during spacecraft powered phases and atmospheric entry.

During the next report period, the interrelationships between entry performance (range), touchdown dispersions (due to platform inaccuracies and initial velocity and position tolerances), and aerodynamic heating characteristics for several entry flight nodes will be evaluated for entry ranges up to 10,000 nautical miles. Guidance and navigation performance criteria are to be conducted. The maximum range capability and performance envelopes study is to be conducted. A method of computing errors for the target-impact point resulting from orbital ejection is to be developed. Additional methods of computing errors will be as follows:

1. Target error as result of inaccuracies in retrothrust vector

2. Target error resulting from uncertainties in initial elliptical orbit

3. Errors resulting from uncertainties in knowledge of absolute time or position

4. Errors resulting from atmospheric variations

Through the use of the "m" body model, iteration (search) logic is being formulated as a means of solving five classes of lunar trajectory problems. These problems include circumlunar trajectories, translunar trajectories, transearth trajectories from lunar orbit, transearth trajectories from lunar surface, and cislunar abort trajectories.

[redacted]

TEMPERATURE-CONTROL COATINGS

The detailed plan of action for evaluation of temperature-control coatings was completed.

Samples were prepared to determine the effect on radiative properties after 14 days of exposure to ultraviolet radiation.

The literature search of temperature-control coatings will be continued.

Measurements will be made of the optical properties of the temperature-control coatings.

SIMULATED SPACE SPHERES

Work on the 4-foot-diameter reinforced fiberglass-sandwich core feasibility study for a space-sphere simulator is approximately 65 percent complete. The first half section of the two-piece sphere has been completed.

Fabrication of the second half-section of the two-piece space-sphere simulator is in progress.

ANTIGRAVITATIONAL SUSPENSION PLATFORM

The anti-gravitational suspension platform has been deferred until completion of the simulated space sphere. In the interim, the design was changed from a 2-foot platform to a 4-foot unit.

Design parameters have been determined, and materials have been procured.

INTEGRATION AND SYSTEM ANALYSIS

CONFIGURATION CONTROL

A serialized and trace method for the hardware used in the Apollo program has been determined.

Inboard profiles of the command module, service module, and escape tower have been prepared. Several systems such as environmental control, reaction control, and their associated hardware are depicted on these drawings. The profiles will be used to determine space allocations and control.

General configuration arrangements for the boilerplate and spacecraft test vehicles have been released. These arrangements will eventually be included in the "Boilerplate and Spacecraft Philosophies and Objectives" document.

Formulation of the integrated systems functional schematics continues. Individual systems schematics have been released. All marked-up system schematics have been incorporated into the basic overall functional diagram. The basic diagram will be distributed for comments.

A report will be published to designate the type of equipment that must be serialized or the lot number that must be controlled. This report will designate the parts and components that will not be serialized. The rules will be in accordance with NASA's publication NPC 200-2.

MAINTENANCE ANALYSIS

Maintenance analysis of boilerplate test and Little Joe II launch vehicles is in progress. Detailed maintenance data required to ensure overall support to the Apollo program are being compiled as engineering drawings are released. Data will be included in scheduled revisions to the Apollo Maintenance Plan.

All known GSE requirements for boilerplate 1 and 2 have been released for manufacturing.

Maintenance analysis of subsequent spacecraft and associated GSE is in progress. Review of requirements for the support of boilerplate testing will continue in order to provide support parts determination.

C[redacted]

SYSTEMS INTEGRATION

Checkout and launch operations of the second Mercury orbital flight were surveyed.

Initial release was made of the operational measurements list and the R & D measurements list for boilerplates 13 and 15. The R & D measurements list for boilerplate 16 and 18 is being compiled.

An integrated system schematic for boilerplate 6 is being prepared, and a revised integrated systems test outline for boilerplate 6 and 20 was completed.

A definition of articles requiring guidance and navigation equipment was compiled and included types of equipment and the dates for delivery.

A schedule was completed for the preparation of test specifications and test procedures to be generated by systems integration.

Studies were made on umbilical requirements, pad prelaunch test requirements, and mechanical systems component-and-system exchangeability.

The checkout interface concept was prepared.

Data for control and display parameter requirements are being gathered for the display and control panels of the command module.

A specification was prepared of the details of the design criteria requirements which are necessary to make the grounding and bonding of the proposed systems integration checkout building (6A) compatible with GSE equipment and other associated electrical and electronic equipment.

A preliminary specification was submitted on the shielded enclosure facility requirements for electromagnetic-interference integrated systems tests of the Apollo spacecraft and GSE.

Studies of stage 1 and 2 of service module B and of configurations compatible with the lunar excursion module were completed. Results of these studies were submitted to NASA.

A preliminary study of the fundamental problems associated with the malfunctions detected at the launch pad is being conducted at the request of NASA.

Specification revisions are being prepared for mock-up 2, 3, 4, and 5, and for boilerplate 6, 12, 19, 20, and 21.

The specifications for mock-up 20 and boilerplate 8 are being revised in accordance with the requests of NASA.

SYSTEMS REQUIREMENTS

Report SID 62-652, "Paraglider Design Data," was prepared and presented to NASA-MSC.

Revisions to the "Spacecraft Performance Specification" (SID 62-51), "Command Module Performance and Interface Specification" (SID 62-52), "Service Module Performance and Interface Specification" (SID 62-53), and "Design Criteria Specification" (SID 62-65) were presented to NASA for approval.

Rough drafts of the logic network for the ascent phase of the mission through suborbital aborts and of the S-II hydraulic subsystem have been completed. The S-II subsystem is being studied to determine the nature of the abort signals to be received by the command module.

PACKAGING AND TRANSPORT SYSTEMS

A plan is being formulated for packaging and transporting the boilerplate aft bulkhead and heat shield from S&ID to Santa Susana for explosive forming. The final packaging method will depend on the cost survey comparing a low-cost package requiring a wide-load escort and a higher-cost package with a narrow load that will not require an escort.

PROJECT PLANNING

A release-system procedure using integrated data processing equipment was studied. Various approaches for automating drawing release information that will include systems which will periodically up-date and revise the information are being considered.

Engineering drawing lists were prepared, reviewed, screened, indexed, and released.

SUBCONTRACTOR RELATIONS

Specific data on some potential recovery ships and a new helicopter, the S-64, are being requested from the Long Beach Naval Shipyard and Sikorsky Aircraft representatives. Upon receipt of data application of the ships and the S-64 data to spacecraft recovery will be investigated.

[redacted]

A letter has been received from Douglas Aircraft Company indicating that it is feasible to modify frame station 1220 on C-133B aircraft. A letter has been initiated requesting that a drawing of this frame station be furnished in order that a more detailed analysis may be performed to determine the necessity for modification and the degree to which the frame should be modified. The loading clearance drawing (DX-31007) for Apollo spacecraft modules was completed and released.

An up-dated issue of the Apollo Hardware Utilization List (SID 62-585) was published on 10 May 1962.

Effort is being made to establish a coordinated list of nonstandard equipment and component items and scheduled procurement-specification release dates. Various inputs have been incorporated into a single document that is being reviewed by the contract specification group for writing-time estimate. Concurrent with the review by the contract specification group, purchasing and program control have been given copies for their advanced planning. Further coordination with purchasing will be required to establish compatibility with procurement lead time to support manufacturing's "need" dates.

[redacted]

RELIABILITY

NAVIGATION AND GUIDANCE RELIABILITY

Apollo reliability and crew safety objectives, statements of work, and S&ID apportionment techniques were discussed with NASA. The telecommunications and stabilization control subsystems were reviewed for the potential of meeting NASA apportionment reliability requirements. The capability of the MIT guidance and navigation subsystem was reviewed, and a presentation was made of the latest reliability estimates. A logic diagram describing the primary and alternate modes of operation was developed by S&ID.

System reliability is to be reviewed for various levels of equipment reliability and for a configuration capable of meeting system requirements.

Cost versus reliability is also to be discussed.

DOCUMENTATION

The Apollo reliability test plan is to be revised with greater emphasis on off-limit, parameter, variability, life, and mission profile simulation tests. Reorientation is required to show deployment and experimental designs in the event of difficulties during qualification or reliability testing. The revised plan will define minimum test programs for each of the spacecraft subsystems.

THRUST VECTOR CONTROL

A reliability prediction study of five thrust vector control configurations for the launch-escape motor has been completed. The configurations included variations of secondary injection and swivel nozzle systems. This prediction study will form a portion of the formal thrust vector control report that will be submitted to NASA.

COMBINED SYSTEMS STUDY

A study was completed on the advisability of integrating radiators for the environmental control and electrical power subsystems. The conclusion from this analysis is that a nonintegrated approach was advantageous for the following reasons:

1. The latter was subject to fewer first-order failure modes

2. There is a greater tolerability to failures

3. System interactions are precluded

SPACECRAFT RELIABILITY

The first reliability prediction study for the Apollo spacecraft has been completed and shows an estimated reliability of 0.731. This analysis assumes all systems as series elements and excludes consideration of alternate modes, redundancies, or in-flight maintenance provisions. The present analysis will provide a base point from which means of improving reliability will be evaluated and formulated.

Studies currently underway are intended to determine the most effective means of employing alternate modes, redundancies, and in-flight maintenance provisions to achieve the 0.960 reliability requirement for the spacecraft.

QUALIFICATION-RELIABILITY TEST MODELS

Methods are presently being developed to determine the reliability of one-shot, high-cost devices when only small sample sizes can be justified for testing. The technique is based upon stress-versus-strength and performance-margin concepts and can yield high confidence statements about the demonstrated reliability.

[redacted]

QUALITY CONTROL

QUALITY CONTROL PLAN

The final Apollo Quality Control Plan (SID 62-154) was submitted to MSC for approval on 1 May 1962. Although written approval has not been received, the plan has been verbally approved by MSC quality control personnel.

QUALITY CONTROL REPRESENTATIVES AT SUBCONTRACTORS

Quality Control representatives have been assigned to AiResearch (Environmental Control System), Minneapolis-Honeywell (Stabilization and Control System), Collins Radio (Telecommunication System), and the Lockheed Propulsion Company (Launch Escape System).

Representatives will also be assigned to Marquardt (Reaction Control Engine), Aerojet General Corporation (Service Propulsion Engine), Pratt & Whitney (Electrical Power System), Thiokol (Tower Jettison Motor), and Northrop-Ventura (Earth Landing System).

Collins' quality control personnel, along with the S&ID representative, visited MSFC at Huntsville, Alabama, to review the organization and administration of the NASA soldering school with the view of implementing similar activities within Collins Radio Company. In addition, Collins is scheduling personnel to attend the instructor course at MSFC.

TRAINING CERTIFICATION

Training and certification of personnel is progressing in three basic categories: (1) soldering, (2) nondestructive testing, and (3) welding. It is anticipated that 102 soldering inspectors certified to the NASA specification MSFC-PROC-158 will be required in the assembly areas. Twenty-five inspectors have so far received this training and have been certified accordingly. Training is continuing in nondestructive testing methods, welding, and quality control orientation.

PROCEDURES AND SPECIFICATIONS

Quality control operating procedures have been revised to reflect the quality provisions contained in NASA Specification NCP 200-2. In addition, there are six procedures being revised and seven new procedures in work.

[redacted]

Copies of the revised manuals have been forwarded to the Reliability Office, MSC, and the Apollo Project Office, MSC.

SERIALIZATION AND LOT CONTROL REQUIREMENTS

During coordination of the Quality Control Plan between S&ID and the Apollo Project Office, agreement could not be reached on paragraph 4.4 entitled "Identification" of NCP 200-2. At that time, it was agreed that the Apollo Project Office would review the requirements of the identification criteria and would submit these requirements to S&ID at a later date. A letter was received from MSC in May requesting S&ID to prepare a plan for the identification of parts and submit to MSC for approval. The plan is currently being developed, and the first rough draft is being coordinated among the various divisions within S&ID.

INSPECTION PLANNING

Mr. Karl Sperber (Flight Safety and Reliability Office, MSC) was at S&ID on 7 and 8 May to review quality control activities. The inspection planning sheets were reviewed in detail and copies were forwarded to Mr. Sperber to aid MSC in developing their inspection plan concurrent with the S&ID's inspection plan.

DATA REQUIREMENTS

Coordination meetings have been held with the Technical Data Group at S&ID to reclassify certain types of quality control documentation currently specified as Type I and Type II data with the view toward reducing the number of reports. Further coordination is to be conducted with NASA for final resolution.

COGNIZANT GOVERNMENT INSPECTION AGENCY

Several major subcontractors have pointed out that the cognizant Government inspection agency has not been specified for their facility. The local NASA project office has stated that they are preparing letters to all major subcontractors specifying the cognizant Government agency that will be assigned to the respective subcontractors.

END-ITEM TEST PLAN

During discussions with MSC quality control personnel, it was agreed that the end-item test plan be eliminated as a separate item. The contents of the end-item test plan, however, will be integrated into the Quality Control Program Plan and the General Test Plan. A letter confirming this agreement was forwarded to NASA on 9 May 1962.

INSTRUMENTATION

R & D INSTRUMENTATION

Information concerning R & D instrumentation systems for the pad abort tests on boilerplate 6 and 20 and the early maximum q abort tests on boilerplate 12, 21, and 23 has provided considerable technical data that have allowed S&ID to proceed with the installation design before official receipt of the measurement requirements and hardware lists from NASA. The location of each of the various transducers was agreed upon by S&ID design groups and NASA. However, certain locations will not be determined until the escape tower design is firm. The details of mounting these transducers were started, and initial estimates of the necessary wire runs have been made. Information on the power dissipation, size, and weight of the various pieces of equipment have been compiled.

Power Requirements

It is planned to carry anthropomorphic dummies on boilerplates 20 and 21. The cameras will be furnished by NASA, and S&ID will be responsible for the lighting. The coordination with NASA has been under way to assure a satisfactory and compatible system. Initial lighting power requirement estimates have been sent to NASA.

Data Storage System

It has been agreed that four digital data channels for recording will be provided. The maximum bit rate per channel will be 32,000 bits per second. S&ID has agreed to provide the maximum allowable outline dimensions for the recorder.

General Purpose Telescope

When the two study programs were completed, telescope requirements were modified. These study programs were direct vision requirement for lunar landing and optical determination of drift after parachute deployment. In order to obtain direct view of the lunar landing point and the landing feet simultaneously without changing the Apollo vehicle configuration, a lunar-landing periscope with a large field of view integrated with a side window will be required. This eliminates the need for a general purpose telescope with large field of view and reduces the complexity of the telescope design.

The second study indicated that with an additional weight penalty from 5 to 10 pounds, an optical drift indicator could easily be incorporated into the general purpose telescope. Present weight estimate for a telescope projecting out of both sides of the vehicle (which will have full hemispheric coverage, two fields of view, magnifications, stadiametric ranging reticle, and drift indicator) is approximately 80 pounds.

OPERATIONAL INSTRUMENTATION SYSTEM

A typical operational measurement list was prepared to assist in establishing the Apollo spacecraft pulse code modulated telemeter and recording systems data capabilities. This list clearly indicates that in-flight programing of data is possible and that the total quantity of measurements required for any phase of the mission is approximately the same.

SPACECRAFT CENTRAL TIMING EQUIPMENT

An evaluation was made to show almost a total mechanical and electrical incompatibility between the research and development elapsed time code generator and the Apollo operational timing and synchronization requirements.

Coordination with NASA will be continued to provide the necessary information for R & D instrumentation installation design for the pad abort spacecraft.

Design effort will be carried on for the abort spacecraft. Coordination concerning the R & D instrumentation system for the first Saturn launches of boilerplate 13 and 15 will be started as will initial design efforts. Proposals for the tape recorder system will be carried on, and preliminary evaluation of potential suppliers will be continued. The initial specifications for the telescope will be prepared. The signal conditioner interface with the in-flight test maintenance (IFTM) system will be investigated for maximum overall system performance with minimum overall signal conditioner system weight. Familiarity with telemetry and signal conditioner systems furnished by NASA will be developed. Equipment requirements for acceptance tests at S&ID will be investigated.

ELECTROMAGNETIC INTERFERENCES

Electromagnetic interference test facilities and equipment requirements have been documented. A control plan for electromagnetic interference is being prepared. A document that describes the Apollo standard electronic package concept was prepared.

[redacted]

CONTROLS AND DISPLAYS

Test results indicate the feasibility of manual control for safe entry using back-up entry display.

The integrated optical display feasibility study was completed and is being evaluated, and the design study was initiated.

Preliminary laboratory effort has been started on the control and display integrator. The effort involves the evaluation and development of components and systems. A roll-rate simulator and lift-velocity indicator were involved in development tests. The lift-velocity indicator was investigated to reduce the size to facilitate mounting on the control and display integrator and the flight chart recorder.

During the next report period, design of the back-up entry display is to be started. Release of a lower equipment bay space allocation and packaging concept document is to be completed. A full-scale mock-up of the lower equipment bay, which will be used to develop an optimum lower equipment arrangement, display installation, and in-flight test system configuration, is to be completed. Layouts of right- and left-hand side consoles are to be started. A demonstration is to be made of the usefulness of the back-up entry display. A precision mock-up will be made of the flight simulator system to simulate identical maneuvers of the manual flight system in the command module. The power supply and other functional subsystems of the control and display integrator will be further developed.

SIMULATION AND TRAINING

TRAINING EQUIPMENT

Training equipment performance specifications (SID 62-496 through SID 62-514) were submitted to NASA for review and comment. The performance specification for the flight trainer (SID 62-515) is being held, pending discussion with NASA.

Visual simulation performance requirements have been incorporated in performance specifications.

Development of mathematical models for the part task and flight trainer computers is continuing as is the development of block diagrams for these trainers.

During the next reporting period, "make or buy" items of equipment and components will be defined; performance specifications will be revised; design criteria for "make" items will be issued; and procurement specifications for "buy" items will be prepared and issued.

TRAINING PLAN

The first revision of the Apollo Training Plan (SID 62-162) has been completed and will be distributed as scheduled. The Training Plan contains expanded coverage of the program in all areas with emphasis on training course development, training support, and contractor participation.

A format for information presentation of the integrated task index has been coordinated with the Life Systems department. This format will supply the task information for the flight crew with specific reference to in-flight task and in-flight maintenance.

Contacts with major subcontractors to determine the status of data required for instructor manual preparation are being maintained.

Coordination with subcontractors, which was initiated in the past two months, is continuing. Inputs to the Apollo training program are being made by Collins, AiResearch, and Minneapolis-Honeywell.

Completion of the Apollo Logistics Training Program Schedules is scheduled for early June. Initial training schedules will be refined, improved, and updated on a continuing basis.

Work on the Apollo training program specifications continues and will be a major effort during the next reporting period.

An integrated study of the revised configuration of part-task trainers to determine training parameters will begin in June. This study will be made in conjunction with life systems personnel and training equipment design personnel.

SIMULATION COORDINATION AND EVALUATION

Lunar Landing Simulation

A lunar landing study was conducted that used most of the simulation equipment built and used in the previous lunar landing study. To simulate landing of the module with the pilot sitting at the access hatch, modifications were made to the capsule. Successful landings were made by two Columbus Division test pilots and a NASA pilot with helicopter experience.

Simulation Studies Summary

A summary report of Apollo simulation studies has been issued and outlines the following:

Master simulation studies phasing plan

Facility schedule summary

Definition of each simulation study

Simulation facility descriptions

This and related documents delineate each simulation study, the computer requirements for each study, the nature and scheduling of engineering evaluators and simulators, the breadboard equipment and prototype hardware required for each study, and the planned utilization of the visual environment simulators and simulated ground consoles.

Simulation Equipment Requirements

Work is under way to define the optimum analog-digital computer complex for Apollo simulations.

NASA approval has not yet been obtained for procurement of the F86 simulator. Possibilities of the Verdan computer tie-in to the F86 simulator are being investigated.

It is expected that the initial installation of the leased analog equipment will be made in June.

Simulation Studies

A 6-degree-of-freedom trajectory was investigated in a study of atmospheric abort, and remechanization was necessitated by a change in the basic data. A study of the reentry 6-degree-of-freedom trajectory is under way, and Phase I of the lunar landing take-off concept is complete.

The following simulation studies will be completed during the next reporting period: Reentry Short-Period Dynamics; Lunar and Earth-Orbit Dynamics, Attitude Control; Translunar-Lunar Orbit-Transition Dynamics; and Orbital Attitude-Control Flight. An effort is being made to finish modifications to the evaluator display panel and commander-pilot couch in order that this study may be started.

The Apollo Simulation Studies Summary report is being revised to reflect the Apollo master phasing plan. A complete simulation study definition will be included for each flight phase.

SPACECRAFT TEST OPERATIONS

ABORT TESTS

Test plans for pad abort testing were included in the Apollo general test plan, and preliminary test range requirements were forwarded to NASA during this period. These documents reflect operational testing, which includes use of air-link monitoring and launching of the test vehicle, and were based on the premise that the test range facilities did not exist with blockhouse provisions.

Discussions between NASA personnel and Apollo system test personnel during the visit of 17 and 18 May to White Sands Missile Range (WSMR) determined that blockhouse capabilities exist to conduct both pad abort tests and the Little Joe II tests. NASA has requested that S&ID prepare the range requirements to support all boilerplate abort tests utilizing the existing blockhouse and test range.

Refinement of the pad abort detail test plans will be accomplished during the next report period. In addition, preparatory effort will be initiated to accumulate and evaluate test requirements for the preparation of Little Joe II detail test plans.

PROPULSION TEST PROGRAMS

S&ID Apollo program management, industrial engineering, and systems test personnel had discussions with NASA concerning consideration of AFMDC/WSMR, White Sands, New Mexico, as the propulsion systems test site. Facility requirements and schedules were coordinated during these discussions.

Planning for the service module stage I propulsion system development test program was accomplished to support the development of the revised Apollo master phasing plan.

The test measurement list was updated to conform with propulsion system design changes, and data acquisitions system performance specifications were revised to include these changes.

Coordination of definitive spacecraft hot-propulsion test requirements will continue in support of detailed test planning. The test facilities design criteria, GSE, and hardware utilization documentation will be reviewed in accordance with firm test requirements.

HOUSE SPACECRAFT AND ACCEPTANCE TESTS

Coordination with engineering is continuing in order to determine the test requirements, the associated GSE, and the facility requirements for the fuel cells and the environmental control systems.

Studies have been initiated to establish overall test requirements and testing techniques for the house spacecraft and acceptance test areas.

Effort will continue on the preparation of program plans for the house spacecraft and acceptance areas.

ENVIRONMENTAL SPACECRAFT

Environmental spacecraft test requirements are being investigated.

The Arnold Engineering Development Center (AEDC) environmental facilities were reviewed with NASA as a preliminary evaluation of the AEDC capabilities.

During the next report period, the primary effort will be made to finalize detailed test requirements; and effort will be initiated on the preparation of a program plan for the environmental proof tests of environmental spacecraft.

FLIGHT DROP AND RECOVERY TESTS

GSE and Apollo systems test support requirements were reviewed, and recommendations were made to Apollo engineering.

S&ID requirements in support to NASA for bailment of a C-133A aircraft for the prequalification flight-drop program have been submitted to NASA.

Logistics engineering was given test information necessary to prepare test operations flow and support charts.

During the next report period primary effort will be to establish the general flight drop and recovery test concept with NASA coordination.

APOLLO/SATURN TEST PROGRAM

Spacecraft subsystems configuration, flight test vehicle configuration, development of integrated systems checkout and countdown procedures to be used at Atlantic Missile Range (AMR), and checkout procedures to be used in the Downey acceptance tests are being monitored.

The detailed test plans for SA 5 and SA 6 are in work.

System requirements will be obtained for the preparation of systems and integrated systems checkout and countdown procedures to be used at AMR and for the Downey acceptance tests.

Detailed test plans for SA 5 and SA 6 will remain as a major effort during the coming reporting period. Coordination with NASA to establish flight objectives and instrumentation measurement requirements will continue.

DATA ENGINEERING

An investigation was performed to determine the expected spacecraft attitude accuracies obtained from phototheodolite cameras. On-board instrumentation will provide the required accuracies for attitude information, and the phototheodolite information can be considered as backup for these data.

Support of the prequalification flight drop-test program will begin during the next report period and will include coordination between S&ID, subcontractor, and the test range.

GENERAL TEST PLAN

The General Test Plan (SID 62-109) has been completely revised and is in final preparation for submittal to NASA on 15 June 1962.

Test support requirements documentation reflecting program requirements have been prepared for all major test areas. Apollo systems test ground support equipment total program requirements have been revised to reflect current program objectives and to provide more efficient utilization of equipment.

Detailed test plans required for the appendix of the General Test Plan will be prepared during the next report period.

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GENERAL TEST SUPPORT

The logic and time interval PERT networks for the Apollo/Saturn test program, spacecraft environmental proof test program, prequalification drop-test program, and service propulsion test program have been completed. Tool requirements for each test site have been compiled.

During the next report period, ground support equipment requirements to support tests of boilerplate 6 and 20, both in acceptance test and field operations, will be prepared.

Operational concepts and procedures for the launch control center, mission control center, and the remote ground operation support system (GOSS) sites will be established.

Revisions and additions to the test support requirements document will be prepared.

CO[redacted]

DOCUMENTATION

MONTHLY PROGRESS

The following S&ID documents were published during May:

SID 62-424	Pretest Report for Apollo Force Model FS-412 in the Arnold Engineering Development Center VKF Hotshot II
SID 62-538	Pretest Report for Apollo Pressure Model (AS-4) in AEDC VKF Hotshot II
SID 62-78	Parachute Recovery Subsystem Specification
SID 62-81	Crew System Subsystem Specification
SID 62-542	Command Module Reaction Control Subsystem Performance Specification
SID 62-541	Service Module Reaction Control Subsystem Performance Specification
SID 62-88	Launch Escape Subsystem Specification
SID 62-82	Environmental Control Subsystem Specification
SID 62-486	Apollo Model (FS-1) Wind Tunnel Test (JPL 20-493B)
SID 62-204	Revised Qualification Reliability Test Plan
SID 62-557	Quarterly Reliability Status Report
SID 62-549	Pretest Report for a 0.030-Scale Apollo Dynamic Stability Model (FD-1) in the JPL Wind Tunnel
SID 62-547	Data Report for Apollo Models FS-1 and FS-7 Wind Tunnel Test (JPL 20-495)
SID 62-509	Propulsion Control Trainer (Preliminary)
SID 62-319	Apollo Space Suit Interface Specification

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SID 62-514	Attitude Control Trainer Specification
SID 62-57	Ground Support Equipment Performance and Interface Specification Volumes I through IV
SID 62-384-4	Drawing List
SID 62-83	Electrical Power Subsystem Specification
SID 62-85	Preliminary Spacecraft Performance Specification Project Apollo Stabilization and Control Subsystem
SID 62-300-3	Monthly Progress Report
SID 62-99-4	Monthly Weight and Balance Report
SID 62-566-1	Project Apollo Still Photographic Submittal No. 1
SID 62-566-2	Project Apollo Still Photographic Submittal No. 2
SID 62-614	Pretest Report for the 0.045-Scale Apollo Heat Transfer Model H-2 in the AEDC VKF
SID 62-154	Quality Control Plan
SID 62-507	Egress Trainer Specification
SID 62-51	Spacecraft Performance Specification (Revised)
SID 62-52	Command Module Specification (Revised)
SID 62-53	Service Module Specification (Revised)
SID 62-50	Ground Support Equipment General Equipment Specification (Revised)
SID 62-65	Apollo Design Criteria (Revised)
SID 62-513	Midcourse Correction Trainer Specification
SID 62-515	Mission Simulator Trainer Specification
SID 62-80	Mission Propulsion Subsystem Specification
SID 62-84	Navigation and Guidance Subsystem Specification

SID 62-384-5	Drawing List
SID 62-510	Earth-Orbital Trainer Preliminary Specification
SID 62-511	Earth-Reentry Trainer Preliminary Specification
	Financial Management Report

LOGISTICS

The initial revision to Section IV of SID 62-96, Apollo Support Plan, was submitted under separate cover letter to NASA 14 May 1962. This section was expanded to include detailed formats and a style guide for the preparation of support manuals. Immediate approval by NASA is required to provide the necessary guidance for S&ID and subcontractor effort. The initial complete revision to the Apollo Support Plan is scheduled for delivery 20 July 1962.

Approval of revised support manual delivery dates submitted to NASA during the last reporting period has not been received. Present work statement schedules will require the submittal of Apollo support manuals on 1 October 1962, which will be subject to extensive revision prior to equipment delivery.

Initial revision to the Apollo Familiarization Support Manual, submitted 30 April 1962, has not been initiated pending approval or comment by NASA.

Preparation of the Spacecraft Operations and Flight Operations Support Manuals and the first revision to the Apollo Maintenance Plan are progressing as scheduled.

CO[redacted]

PROGRAM MANAGEMENT

S&ID visited NASA to discuss the contract, the statement of work, pricing, and various unresolved aspects of contracts. From this meeting, a number of action items evolved; most of these items have since been answered.

Contract Amendment No. 1, which increased the funding from 32 million to 55 million dollars and extended the date for definitization of the letter contract from 6 May 1962 to 30 September 1962, was received. The document was executed by S&ID and returned to NASA on 11 May 1962.

Contract Amendments 2, 3, and 4 have been received and are presently being reviewed. It is anticipated that these documents will have been fully reviewed and prepared to be returned to NASA on or before 9 June 1962.

The definitive cost proposal is proceeding on schedule. In accordance with NASA direction, however, work on the cost proposal was stopped for two weeks. This will adversely effect the scheduled delivery date to NASA. The statement of work is being prepared as a part of a proposed definitive contract and is approximately 35 percent complete but it is subject to further review. A proposed contract schedule for the definitive contract has been completed.

PERT

S&ID presented preliminary copies of the following networks for review at the Manned Spacecraft Center, Houston, Texas: documentation, crew provisions, communications subsystem, and service propulsion subsystem. S&ID met the NASA PERT network delivery requirement. All networks required by NASA have been presented to NASA at Houston.

During the report period, Apollo PERT systems coordinators and S&ID PERT systems coordinators visited Thiokol Chemical Corporation, Elkton, Maryland. A previously submitted Thiokol PERT network was coordinated with a network recently submitted to NASA and was updated to reflect recent changes in the Apollo program. Information and guidance furnished to Thiokol by PERT systems should enable Thiokol to present meaningful information and network representations for inclusion in the customer network.

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INSPECTION PLANNING STATUS

The mechanics of integration of inspection test instructions with production planning tickets is being developed. Several advantages will result from the combining of these functions. For example, inspection will follow manufacturing in sequence. Planning tickets will also be issued for each part rather than for each release. These features will provide improved historical documentation.

PROGRAM MANAGEMENT

The initial meeting between NASA, Convair, and S&ID personnel concerning the Little Joe II booster interface with S&ID-produced equipment was held at Downey on 25 May. At this meeting, arrangements were outlined for working out future communications with Convair.

Coordination with MIT primarily concerned the space allocation within the command module for navigation and guidance equipment.

NASA has been advised by letter of our recommendations regarding the navigation and guidance systems hardware and schedules requirements.

S&ID attended the initial meeting of NASA and the navigation and guidance participating contractors at Houston on 22 May. Working relationships of S&ID and the participating contractors will be established in subsequent meetings with NASA, MIT, and the participating contractors.

SUBCONTRACTOR RELATIONS

Visits to interested vendors were made by representatives of S&ID and Collins Radio. Vendors visited, briefed, and inspected were as follows:

Precision Instruments, Inc., Redwood City, California

Ampex, Redwood City, California

Leach Relay, Azusa, California

Weber Aircraft, Burbank, California

Ralph E. Parsons, Pasadena, California

A trip was made to Texas Instruments, Inc., to obtain updated information on the NASA elapsed-time code generator.

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The Collins Radio interface with IFTS was presented to Collins and was found generally compatible. A team of 10 Sperry Utah men started a back-up concept study contract of about eight weeks duration.

STABILIZATION AND CONTROL

ANALYSIS

Several control schemes for effecting attitude control during orbital phases of flight have been studied. Simplified vehicle equations of motion and control system configurations have been defined for evaluation and optimization.

The recent NASA decision to eliminate lunar landing of the command and service modules has necessitated further study of the reaction-jet thrusts for both modules.

A report summarizing preliminary duty cycle and fuel consumption data generated by an analog computer study is being prepared. Another analog study initiated will investigate the entry problem associated with high-altitude abort.

A preliminary report on the integrated method of providing the required midcourse three-axis orientation and antenna pointing has been prepared.

A new preliminary configuration of the launch escape stabilization and control system is undergoing investigation. This configuration is essentially a rate system. The value of this configuration is being defined by analog investigations.

The study of stabilization and control interface areas with the reaction control rocket engines has been completed.

Requirements have been established for the sun seeker, and a final report will be submitted 15 June 1962.

The preliminary on-board monitor conceptual study has been completed.

System requirements for a back-up inertial attitude reference have been established and three system mechanizations have been defined.

DESIGN

The procurement specification for the prototype stabilization and control system has been completed.

Space for the electronic equipment in the lower equipment bay has been allocated. The final packaging criteria specification will be ready 15 June 1962.

During the next reporting period, the preliminary installation layouts for the boilerplate launch escape stabilization control system and a review of the controls and displays will be completed.

System optimization and performance evaluation investigations of the thrust vector control and the orbital control systems will be made.

Possible reaction-jet thrust and/or control system requirements will be determined by a study of the entry problem associated with high-altitude abort.

The detailed study of reaction-jet thrusts requirements for the command and service modules will be completed.

Switching logic and stabilization systems for rendezvous and small velocity-change corrections will be studied; various control schemes will be proposed for analog computer evaluation.

CREW PROVISIONS

CABIN ARRANGEMENT

A study concerning the relocation of pressure suit oxygen connections and the rerouting of shirt sleeve environment plumbing has been completed. The study resulted in the removal of plumbing from the electronic equipment bay.

An analysis to evalute the feasibility of the environmental and indirect lighting systems of the command module was completed. The lighting-fixture design and layout for boilerplate 2 were completed.

Drawings of the shock-mounted and hard-mounted lighting fixtures for boilerplate drops, the airlock entry study layout, and the interface controller arm rest were completed.

The primary display panel layout drawing was revised and the sleep-curtain drawing was submitted for fabrication of mock-up 2 and 3.

CREW COUCH DESIGN

The pad assembly drawing and a revision of the simulator 1 couch drawing were released.

The work-information drawing delineating modifications to the couch-headrest adjustment mechanism for the performance analyzer was revised.

PERSONAL EQUIPMENT

A study of the chemical and physical properties of Velcro has been initiated to determine possible applications in personal equipment.

An Apollo space suit interface specification that will be satisfactory to both NASA and S&ID is being prepared.

FOOD MANAGEMENT AND WATER SUPPLY

The basic criteria have been established for artificial survival food and emergency eating procedures.

An evaluation was made of the possible use of synthetic nutrients in powdered or aqueous form as a food-and-water supply for the flight crew.

The potential use of either coated mylar (Scotchpak) or polypropylene film (in the form of variable-sized heat-sealed bags) was established for (1) fecal matter storage and (2) food containers.

A preliminary investigation was conducted into the feasibility of a program for the development of biosensors, simulated viscera, and moulages. A study was made of the requirements to obtain property data on biological inert materials.

WASTE MANAGEMENT

A vacuumized commode prototype was completed and is undergoing tests.

CREW ANALYSIS

Procedures for psychomotor and psychological testing are being prepared for use in confinement studies and crew tests.

A matrix format that will apply to flight profiles was completed for in-flight maintenance analysis and procedure.

A preliminary draft of a test plan to evaluate simulator 1 airlock, hatch, windows, couches, and duty stations was completed.

Studies of crewman tasks during the prelaunch phase are being conducted.

A preliminary study of possible atmospheric contaminant sources in the Apollo spacecraft has been initiated.

A preliminary trade-off study of command module crew positions was completed.

A study of the abort criteria and the duties relative to the scientist crew member is under consideration.

SIMULATION AND TEST

Preliminary planning for the control-layout modification and the microbiological airlock was completed.

Acceleration profiles were completed for the Apollo mission launch, earth entry, recovery, and all abort conditions.

CONTROLS AND DISPLAYS

A document is being prepared that will contain a proposed concept for the side consoles of the command module and suggestions for necessary relocations of equipment.

The primary console drawing for mock-up 2 and 3 was completed.

The following activities are planned for the next report period:

The first boilerplate drawing will be released.

Instrumentation will be installed, and tower drop tests will be initiated.

Anthropometric dummy specifications and a list of mandatory instrumentation requirements will be prepared.

Test plans and procedures will be reviewed for the first test series.

Work on the in-flight maintenance test system and associated panels will be continued.

Manual backup study and tests will be continued on the window layout and visual navigation system.

The Apollo Flight Crew Performance Specification and the Preliminary Spacecraft Systems Monitoring Personnel Specification will be updated to reflect the latest available information.

The Human Factors Ground Support Checklist will be ready for publication, and the Design Criteria Handbook for Life Systems GSE will be published.

The Human Engineering Design Criteria for Apollo will be ready for publication.

SUBCONTRACTS

The Whirlpool Corporation completed studies pertaining to fecal collection bags and other waste-management techniques. These studies are being reviewed for possible applications to the Apollo spacecraft. Subcontracting these studies was necessitated by the procurement difficulties experienced in acquiring dielectric and ultrasonic-sealing laboratory equipment.

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It was determined that the following fields should also be subcontracted:

1. Development of biosensors
2. Development of simulated viscera
3. Development of moulages
4. Property data on biological inert materials

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LAUNCH ESCAPE SYSTEM

STRUCTURAL DESIGN

Detail drawings of the launch escape system (LES) structure have been prepared to reflect the nozzle cant-angle change and to incorporate aft closure bulkhead and nozzle installation design.

The launch escape motor-to-structural skirt interface control drawing has been completed.

Tower-jettison motor to launch escape motor interface and nose cone to jettison motor interface drawings are under way.

Nose cone layouts have been initiated.

Location, size, and shape of two-system tunnels for electrical wiring are under design study.

During the next report period, electrical and control circuitry requirements will be completed; all structural interface drawings will be completed; and electrical raceways and ground support equipment will be defined.

LAUNCH ESCAPE MOTOR

Design of a movable-nozzle, thrust-vector control system began. Actuator procurement specifications were completed. Design of the hydraulic system, process tooling, special test equipment, and igniter design are nearing completion. The igniter system design incorporates exploding bridge-wire squibs.

During the next reporting period, design and procurement activities will proceed; and acquisition of hardware will begin.

TOWER JETTISON MOTOR

Six 8-inch motor firing tests of the scarfed nozzle design indicated that the thrust vector was deflected only about five degrees from the nozzle mechanical centerline. Internal ballistic design for the full-scale jettison motor is being developed on this basis.

Tooling for case and closure was begun. Nozzle and igniter design was completed and design of the interstage structure is in progress.

During the next report period, testing and fabrication tooling acquisition will be initiated; and process specifications for propellant manufacturing will be prepared.

MOCK-UP

The initial fabrication of the escape tower portion of mock-up 18 and 19 is scheduled to begin in June.

ENVIRONMENTAL CONTROL SYSTEM

A revision was completed of the schematic and system specification of the environmental control system (ECS) incorporating current design changes.

An ECS package that contains most of the major components has been arranged. This package can be replaced as a unit.

The possibility of integrating ECS and electrical power system cooling was studied. This concept was rejected because of the weight penalty that would result from using a larger, deployable, radiator-support structure. (Redirection to a lunar orbit employs fixes radiators.)

Research and engineering development tests were performed on a wick-type, zero-g, alternate water separator. If further testing proves the design feasible, it will be considered as a possible replacement for the sponge-type separator.

MOCK-UP

Approximately 75 percent of the mock-up information was released. All ECS equipment was installed in the aft equipment bay, and the ECS package components were fabricated.

WATER MANAGEMENT SYSTEM

The water management cooling and potable water tank is now installed in the command module, thereby reducing line weight and pressure drop. The fill disconnect remains in the service module.

LIQUID COOLING SYSTEM

To provide a more even glycol temperature at the electronic coldplate inlets, the regenerative heat exchanger for cabin heating was replaced by fluid mixing. Another advantage realized from this arrangement is that it can be easily expanded when heat from the service module coolant loop is required for command module heating.

CABIN ATMOSPHERIC CONTROL

A fourth recirculation receptacle was added to the cabin distribution system in the area of the sleeping crewman.

LABORATORY TESTS

Aluminum Coldplates

Preliminary results of aluminum coldplate fabrication by dip brazing indicate that channel depths of 0.030 to 0.050-inches are reliably producible without closure by braze-alloy flow. Future efforts will include the development of flux removal techniques, the evaluation of a new molten salt with greater fluidity, and the production of a prototype coldplate.

Coldplate tests were conducted on 3- by 3-inch aluminum plates to determine interface conductance under ambient conditions and simulated altitudes in excess of 300,000 feet. Various surface finishes with and without vacuum greases were tested. A set of bonded aluminum plates was similarly evaluated.

Breadboard Tests

Equipment specifications were prepared and released. Further investigation of a three-man metabolic simulator is continuing. It is expected that design will be completed and fabrication will be started on the test setup for the metabolic simulator.

Command Module Interior

The environmental requirements for the interior of the Apollo command module were changed from 4 days at 7.5×10^{-10} Torr to 40 days at 1×10^{-4} Torr. Because of this major change, it will be necessary to rewrite the plan of action.

Leakage Tests

The test set-up design and test procedure for O-ring leakage tests under space environments was completed; the acquisition of parts and equipment was started; fabrication was begun.

During the next report period, proposal evaluation of the supercritical gas storage system will be completed.

Performance testing of the ECS breadboard will be conducted in a vacuum chamber to preclude an influx of ambient air as well as an upset of partial pressure balance and total static pressure.

Viton O-rings will be tested at 10^{-9} mm Hg.

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In connection with research and engineering breadboard tests, one of two existing sets of ECS hardware will be investigated for basic operating principles.

Test preparations are in progress for full-scale coldplates. The testing of several 9- by 15-inch coldplate assemblies is to be accomplished.

The modification of a high-vacuum test chamber will continue.

The fabrication of feedthroughs for the coldplate tests will continue.

Detail drawings of the test chamber for housing the breadboard of the ECS will be completed.

EARTH LANDING SYSTEM

BOILERPLATE

The test parachute attach points were removed from the center point of both the forward and aft heat shields of boilerplate 3, 5, and 19 since these fittings added too much weight to the forward heat shield. The attach points were relocated to the upper and lower ground support equipment holddown-fitting hard points on the body of the command module.

Ground support equipment requirements for boilerplate 3, 5 and 19 have been defined.

No parachute data instrumentation is planned for boilerplate 6, 12, 20 and 21 because tested parachute systems will not be available at the time of the scheduled drop test.

PARACHUTES

A general investigation of parachute deployment was instituted to increase reliability and to decrease weight and volume. The system synthesized calls for the heat shield to be ejected from the command module by two thruster cylinders before mortars fire the two drogue chutes. The drogues attached to the command module provide stability, and the three pilot chutes are then deployed by mortars. The pilot chutes deploy the three main parachutes.

A study of solid conic parachutes has been initiated.

SEPARATION SYSTEMS

The system selected to eject the forward heat shield from the command module employs two gas generators; each generator supplies pressure to two opposite thruster cylinders. Detail design of the gas-generator cable-chopper unit is in progress.

All detail part drawings of the escape tower separation system have been completed.

IMPACT ATTENUATION

Documentation of an impact attenuation trade-off study was completed.

COMMUNICATION SYSTEM

RADIO RECOVERY AIDS

Effort to evaluate the equipment requirements for radio recovery aids has continued with the gathering of additional information on the performance capabilities of existing beacon and aircraft receiving equipment. Information obtained to date indicates that the VHF recovery beacon equipment should be operable in either a modulated continuous wave (MCW) or long-pulse mode in order to be compatible with existing aircraft equipment. The results of this investigation will be incorporated in a report covering the recommended system.

Study of recovery aids will be continued in order to firm up equipment requirements.

A study program has been outlined aimed at defining bounds for the effects of reentry blackout on communications. Initial effort in this area will be small until study results indicate that additional effort is warranted. Initial study will involve predication of plasma electrical properties from preliminary evaluation of flow fluid characteristics.

Analysis effort will be initiated on the study of reentry blackout effects.

MODULATION TECHNIQUES

A comparative analysis of modulation techniques for voice, telemetry, and TV communications is still in progress. Question areas involve frequency allocation, duration of ranging requirements, and results of the analog versus digital TV studies.

PERSONAL COMMUNICATION RELAY TRANSCEIVER

A study program has been initiated in order to determine the optimum personal communication equipment. The areas to be covered in this study include the optimum frequencies of operation, modulation techniques, and the feasibility of using existing spacecraft equipment for receiving from and transmitting to the belt pack during lunar exploration.

An investigation will be made into the change in requirements for the spacecraft communications equipment in order to be compatible with the lunar excursion module.

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TELEMETRY EQUIPMENT

The following items were completed for the pulse code modulated (PCM) telemetry equipment: preliminary power consumption and weight estimates, a system block diagram, a format timing chart, resolution of GSE and in-flight test maintenance (IFTM) interface, resolution of tape recorder interface, and establishment of telemetry input signal levels. The following studies were conducted on the PCM telemetry system: error correction in the a-to-d converter, programing techniques, intrawiring considerations, calibration techniques, computer interface, and data compression considerations.

The preliminary telemetry equipment procurement specification under preparation will conform to operational measurement requirements. A number of PCM telemetry study items previously mentioned will be continued.

TELEVISION EQUIPMENT

A study of TV synchronization methods has continued to develop a reliable method. Preparations are under way for conducting closed-circuit TV tests in conjunction with fiber optics equipment. TV synchronization method studies will be continued.

GROUND-TO-SPACE DATA MISSION

Preliminary estimates of equipment size, weight, and power consumption were calculated. The ground-to-spacecraft data transmission study will be continued to attain a definite recommendation in the near future.

Three completed specifications provide antennas for pad abort, Little Joe II, and spacecraft SA 5 through SA 8. The service module antenna specification is written and will be released by engineering. This specification provides antenna equipment for spacecraft SA 5 through SA 10. The telemetry radome specification for SA 9 and subsequent spacecraft is nearing completion.

A design evaluation is being made to determine feasibility of retaining the VHF discone antenna through the operational landing and recovery mission phases.

The effect of the temperature of the radome on the parachute is a limiting factor.

During the next report period, investigation of modulation and multiplexing techniques will be continued with further investigation into deep-space instrumentation facility (DSIF) ranging requirements and frequency allocation.

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NAVIGATION AND GUIDANCE INTEGRATION

NAVIGATION AND GUIDANCE SYSTEM INSTALLATION PROBLEM

The present preliminary drawing layout of the service shelf for food preparation and maintenance is located between the inertial measurement unit (IMU) and the computer volumes. The design concept is a slide-in shelf with a cut-away to allow direct intra-unit cabling between the IMU and the guidance and navigation computer.

NAVIGATION AND GUIDANCE PERFORMANCE REQUIREMENT

Details of the guidance and navigation performance requirements upon spacecraft stabilization and control were generated, and a study with stabilization and control was made. The results were presented to NASA, and further details of the spacecraft maneuvers required for navigation sightings and sextant operation were discussed.

NAVIGATION AND GUIDANCE SYSTEM INTEGRATION ANALYSIS

A preliminary evaluation was made of requirements for guidance and navigation simulation during testing. Consideration was given to both spacecraft systems and GSE testing.

During the next report period, an evaluation is to be completed of the backup and abort modes required to attain the assigned guidance and navigation system reliability.

Operating modes and equipment configurations are being considered for the lunar excursion vehicle, ground operational support system (GOSS) supported operation, and strapdown backup inertial modes.

ASCENT AND ASCENT MONITOR GUIDANCE

An examination of the path-adaptive guidance computations has been made. The preliminary conclusion is that the equations provide only a minimum of information necessary for an in-flight evaluation of the ascent trajectory. The two quantities are computed as the desired present motor deflection angle for a minimum-propellant, optimized trajectory to the specified ascent-phase termination conditions and the time to cutoff. Both of these quantities are computed from empirical expressions that in no way determine how well the ascent is proceeding. Computations must be devised for this purpose.

APOLLO ENTRY GUIDANCE

An approximate closed-form solution has been determined to the nonlinear equations of motion for primary guidance steering. The range of validity is being checked. This closed-form solution should solve the entry ranging problem (large range flexibility). It is expected that this steering method will be checked out on the IBM 7090 digital computer shortly.

SUBORBITAL LAUNCH ABORT GUIDANCE

A study is being made of using the explicit guidance technique for suborbital launch abort.

BACKUP ABORT GUIDANCE

A study of backup guidance for the earth-orbital missions is being conducted. Project Mercury documents are being reviewed to establish a minimum backup guidance system for orbit keeping and for deorbit.

APOLLO VEHICLE STABILIZATION REQUIREMENT FOR STELLAR NAVIGATION

Investigations have been made of the determination of required vehicle maneuvers for midcourse navigational fixes using the space sextant. The following problems were examined:

1. Before maneuver, the determination of the directions of objects to be viewed relative to vehicle axes given the coordinates of the objects (declination and right ascension of a star or latitude and longitude of a point on the surface of the earth) and coarse vehicle attitude from the guidance system.

2. The determination of the ranges (imposed by the sextant optics) of viewable object pairs in sextant coordinates, the interpretation of these ranges in terms of the implied range in vehicle maneuvers to satisfy the viewing requirement.

3. A rough examination of the dynamics of the vehicle involved in the execution of the intended maneuver under the assumption of a diagonalized inertia tensor, small pitch and yaw rates, and a roll command. The result is the reduction of the Euler dynamic equations to a less formidable (but still nonlinear) set of differential equations in the maneuver Euler angles.

4. Studies are now being conducted to determine the accuracy requirement of vehicle stabilization to attain the required midcourse fixes for navigation accuracy.

GUIDANCE OPTIMIZATION METHOD STUDY

A report that discusses the application of the zeta-transformation to the analysis of numerical algorithms has been completed. This effort was conducted to develop performance criteria for computer program mechanization.

A study was initiated to investigate the application of Pontryagin's maximum principle to the various guidance and navigation tasks of the Apollo mission. At present, preliminary studies of the theory involved in the application have been completed. Several problem areas in this application are presently being studied.

During the next report period, an ascent trajectory simulation program will be completed for immediate use in evaluating the path-adaptive guidance technique with respect to general characteristics and guidance cutoff errors for orbital and translunar injection.

A study of control errors due to variations in air density at high altitudes is under way.

A strap-down guidance scheme for entry backup guidance has been formulated. Two methods of steering being investigated are the acceleration profile method and the adjoint method.

The generalized error equations are being written. These equations will be programed on the IBM 7090 computer and will be capable of handling all IMU error analysis.

MOD 3C COMPUTER FUNCTIONAL SIMULATOR

The IBM 7090 functional simulator is 60 percent complete. The basic arithmetic and control section flow charts and coding have been completed. These sections are being debugged and a flow chart of information for input-output is being prepared.

COMPUTER TELEMETRY

A report has been written concerning the latest information to the approach for a down telemetry system.

COMPUTER DYNAMIC FLIGHT SIMULATORS

The guidance and navigation and stabilization and control system (SCS) preliminary dynamic flight simulation plan has been completed for the first two phases and work is continuing on the third phase (hybrid simulation).

COMPUTER MISSION PROFILE

A computer mission profile has been initiated to summarize the functions of the computer throughout the different mission phases.

RADAR REQUIREMENT

A meeting was held with MIT personnel to discuss the radar requirement. The discussion centered on the type of radar required for rendezvous and lunar landing operation using the Apollo vehicle configuration of $C/M\text{-}S/M_A$, $S/M_B\text{-}LBM$, and the location of the radar equipment. This requirement has been superseded by requirements as yet to be defined pending study of the lunar excursion module concept.

COMMAND MODULE STRUCTURE AND SUBSYSTEM INSTALLATION

MOCK-UP

The structural portions of mock-up 2 and 3 (cabin interior arrangement) were completed. Fabrication of system components is proceeding. S&ID is attempting to show NASA a mock-up with all systems. Seat travel, functional equipment compartment drawers, and accessibility to equipment will be demonstrated. An airlock has been added to mock-up 2 and 3. Structural design of mock-up 5 (exterior equipment) and mock-up 8 (airlock and docking) continues. Since mock-up 2 and 3 are identical, all effort will be concentrated on mock-up 3. Fabrication of mock-up 9 continues.

During the next report period, mock-up 2, 3, and 5 will be completed. Construction of the command module portion of complete mock-up 18 and 19 will begin.

BOILERPLATE

Specific boilerplate status is reflected in Table 2.

Major efforts centered on boilerplate 6 and 9, and the basic structure designed for these articles will be used on all subsequent boilerplate. The outside configuration will approximate the ablative mold line.

Boilerplate 6 and 9 incorporate the prototype concepts: slant wall compartment, main hatch redesign, and aft heat shield displacement of 3 inches.

Other design changes incorporated in boilerplate 6, 9, and 20 are as follows:

1. Utilization of an essentially pressure-tight module so that dynamic pressure loads are partially reacted by internal pressure, primarily during maximum boost pressure; maintenance of internal pressure during the total mission will not be required.

2. The command module will be split into a forward structure assembly and an aft structure assembly, effecting a mating of both halves through a bolted joint at the kick ring. The aft heat

[redacted]

Table 2. Boilerplate Status

Boilerplate	Nomenclature	Status	Remarks
1	Land impact	Initial drawings released Fabrication continues To be completed 29 June with exception of crew seat impact attenuation system	Aft bulkhead assemblies being redesigned to add seat strut fittings, rubbing plates for seat loads, small fittings, and test support fittings.
2	Second land impact	Vertical shock strut layout completed Attenuator cylinder locations are being redesigned Final assembly drawings initiated Subassembly 65 percent complete	This item weighs about 70 lb less than the vertical shock strut of B/P 1, 3, and 10. This shock strut to be used on all subsequent B/P
3	Air drop	All detail drawings complete except for forward compartment cover Final assembly drawings initiated Final assembly structure 60 percent complete Welding of outer structure 90 percent complete	Some of small fittings used on B/P 1 can be used on B/P 3
5	Prequalification flight drop	Detail fabrication 67 percent complete	Some basic structural drawings of parts designed for B/P 6, 9, and 20 will be used for this and all subsequent test articles
6	Pad abort test article	Design initiated and drawings 40 percent complete Subassembly 50 percent complete	Outer configuration approximates ablative mold line
9	Dynamic test article	Subassembly 17 percent complete	B/P subsequent to 6 and 9 will employ same basic design shock strut designed for B/P 2
20	Pad abort test article	Mechanization layout started Detail fabrication 90 percent complete	[the above applies to B/P 6, 9, and 20]
14	House spacecraft No. 1	Detail drawings completed	
19	Prequalification flight drop	Detail drawings being completed Subassembly 80 percent complete	Drawings of forward compartment cover and aft bulkhead used for B/P will be incorporated into this article
12	Little Joe II - Max q abort article	Detail fabrication 45 percent complete	
13	First C-1 launch (SA 5)	Detail fabrication 22 percent complete	

[redacted]

shield is to be lightened, thereby more nearly approximating the stiffness of the aft heat shield of the spacecraft.

3. Service module-to-command module hard points for thrust loads also will be incorporated into this design.

PROTOTYPE

Initial efforts on the prototype crew couch were to study use of the center couch for supporting a crewman at the astrosextant during lunar approach. Displacement of outboard couches for access to equipment areas was also investigated.

A review of the total number of angular and linear adjustments continues, and efforts will be made to reduce this number.

An investigation of high strength-to-weight ratio materials is being made to keep our knowledge of couch fabrication current.

HONEYCOMB SANDWICH STUDIES

Three of five alloys for brazing René 41 sandwich material produced qualifying joints without degradation of the sandwich materials.

Honeycomb panels fabricated of L605 cobalt base alloy were brazed with an alloy melting at 1950 F and, when tested, had a remelt temperature of 2000 F. Mechanical properties were also determined.

Titanium honeycomb sandwich tests for mechanical properties were made from room temperature to 800 F.

THERMOPHYSICAL PROPERTIES

Work has started on the design and development of a high-temperature volume expansion measuring apparatus. This device will permit the determination of the temperature-density variations of solid materials. Studies of apparent thermal conductance on brazed stainless steel honeycomb panels from approximately 150 F to 900 F have been performed. Plans of action to determine thermal properties of honeycomb sandwich composites and of ablative materials have been written.

FORGED RINGS

A specification for the forged ring used in the inner cabin of the command module has been released. The specification defines the

[redacted]

metallurgical microstructure requirements necessary to produce crack-free welds in forgings. Roll-ring forgings are also being considered. If these can provide the specified quality, significant tooling cost savings would be achieved. A test plan was written for comparative evaluation of ring forgings and hand forgings simulating a die forging.

COLDPLATES

An adhesive bonded, CHEM-MILL plate design has been fabricated and is undergoing a series of specific cooling rate tests.

ADHESIVE BONDING

Plans of action have been approved for a two-phase evaluation program on the effect of Apollo environments on adhesive systems in structural bonding applications.

AIRLOCK AND DOCKING

A preliminary requirement outline for space docking has been written. This outline assumes that the mating vehicles can be navigated to within a few feet of each other and held to a relative velocity of less than 6 inches per second and that the capsules can be steered to within a few inches of axial alignment and parallelism. Another assumption is that the crewman in the airlock is adequately protected against radiation and meteoric bombardment and is physically capable of grasping the mating vehicle and maneuvering it to the sealing faces for final clamp.

OBSERVATION WINDOWS

Layouts have been made of three observation window configurations. A vision study disclosed that sufficient direct vision for lunar landing is not feasible, nor can any observation window be uncovered during reentry.

HEAT SHIELD

Apollo Test Requirements

All test article assembly drawings are in work. The forward compartment heat shield jettison mechanism has been defined and is being incorporated on the assembly drawing. The new horizontal landing impact attenuation shock strut attach fitting will be incorporated into the aft compartment heat shield assembly drawing.

[redacted]

Aft Compartment

The aft compartment heat shield attach fittings were redesigned because of the loads imposed by the new shock struts of the impact attenuation system.

Several configuration studies of the insulation between the aft bulkhead and heat shield proved that it is feasible to remove the beams from the inner structure of the aft bulkhead. This change is also being incorporated in the redesign.

Forward Compartment

The basic design layout of the forward compartment heat shield is being revised to incorporate changes resulting from the new parachute deployment sequence. The housing surrounding the attitude control rocket engines has been replaced by a truss structure that will support the engines after heat shield jettison. The crew compartment heat shield-to-forward compartment heat shield separation plane has been relocated to accomodate the guidance system sextant.

Crew Compartment

Design studies indicate that the crew compartment heat shield will be rigidly attached to the inner structure and to the forward and aft compartment heat shields. Expansion due to thermal gradients across the structure will be restrained and the stresses induced will be absorbed in both the inner structure and heat shield.

A study is under way to determine the feasibility of using fiberglass instead of PH15-7MO Cres steel for the crew compartment heat shield-to-inner structure attach stringers.

Total cabin wall penetrations and percentage of leakage allowable for each penetration are being determined by listing all penetrations combined with the length of the seal, type of seal, and type of equipment operating through the penetration.

IMPACT ATTENUATION

A decision to increase the vertical deployment stroke (to 14.3 inches) resulted from a review of heat shield structure and weight. The new shock strut configuration provides sufficient clearance between the inner structure and the heat shield and allows yield deflections of the heat shield under certain landing conditions. The additional weight of the longer struts is considerably less than the material weight required to stiffen the heat shield structure.

[redacted]

The layout for the airframe vertical shock strut for boilerplate 2 and subsequent boilerplate is being detailed. The layout for the horizontal shock strut for the same application is in work.

Testing and investigation of various energy-absorbing materials is continuing to find materials with a high-weight and volume energy-absorbing efficiency. The emphasis of this investigation is directed toward metal foams, honeycombs, and like materials.

A vertical drop-test fixture for individual tests of impact attenuation components is being fabricated.

CREW HATCH

S&ID decided to retain the inward-opening, pull-down concept that uses plain through bolts for lower sill attachment, and a manual jack-screw device that supplies the force necessary to seat and unseat the hatch. The bolts provide seal clamp-up and efficient transfer of pressure vessel loads.

Concurrently, a number of latching concepts will be presented to NASA, including that of an outward, quick-opening crew door without an outer emergency panel. The latter concept, however, has weight and complexity disadvantages, plus the continuing requirement for explosive initiation.

SYSTEM EQUIPMENT INSTALLATION

Forward Compartment

A new control drawing is being made and will be used as a basis for solving equipment installation problems as equipment becomes defined.

Crew Compartment

S&ID gave MIT the following drawings for coordination:

1. Guidance and navigation equipment space allocation and clearance requirements in the lower equipment bay

2. Lower equipment bay structural diagram

3. A preliminary concept of the inner structure sealing around the sextant-telescope cutout

4. A preliminary proposal for the heat shield doors covering the sextant and the sextant and telescope opening

5. A sketch of a crewman seated on the lower position of the center couch

The crew compartment control drawing is being revised to reflect an increase in size of the forward equipment bays and the resultant equipment relocation as well as the rearrangement of the lower equipment bay. The layout of the environmental control equipment support structure in the left hand bay is continuing.

Aft Compartment

The proposed reorientation of the command module on the launch pad requires that the ground support equipment remote tower umbilical be shifted approximately 180 degrees from its present location. This revision can be accomplished by stacking the yaw engines in a vertical arrangement.

A new aft compartment equipment layout has been started to incorporate this change as well as the following:

1. Increased propellant tank sizes

2. Reduced propellant pressurization storage from two helium tanks to one larger tank

3. Revised shock attenuation system

4. Reduced urine storage requirement and relocation of the environmental controls system waste water tank from the service module

Paraglider Installation

Results of a preliminary design study indicate equipment installation revisions would be required in the forward and aft compartments.

LAUNCH PAD SERVICE

The control layout that defines location of external service points for the command module and escape tower has been completed. This layout defines access requirements to be supplied by pad 39 and two other launch sites. Access doors for equipment service are also defined.

COMMAND MODULE STRUCTURE

The aft bulkhead dish for boilerplate 1 was accepted by inspection on 24 May, and welding beams has been completed. The dish for boilerplate 3 has not yet been accepted due to porosity areas appearing under X-ray inspection. S&ID Inspection has assigned a representative as liaison to the vendor for the solution to this problem. Further progress on boilerplate 1 was marked by completion of both the outer structure welding and welding of the longerons to the inner structure. Welding of the outer structure for boilerplate 3 is 90 percent complete.

The following activity is scheduled during June:

Boilerplate	Activity
1	Completed 29 June with exception of crew seat impact attenuation system
3	Final assembly structure 60 percent complete
19	Subassembly 80 percent complete
2	Subassembly 65 percent complete
6	Subassembly 50 percent complete
9	Subassembly 17 percent
20	Detail fabrication 90 percent complete
5	Detail fabrication 67 percent complete
12	Detail fabrication 45 percent complete
13	Detail fabrication 22 percent complete

A full report on the resolution of the porosity problem is expected by 6 June.

The structural portions of mock-up 2 and 3 (cabin interior arrangement) were completed. Recent engineering design changes have seriously affected

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the feasibility of meeting the preliminary design evaluation and investigation date of 15 June. Since mock-up 2 and 3 are identical, all effort will be concentrated on 3. Mock-up 5 is on schedule with the installation of dummy tanks, valves, and motors, bringing the installation effort to 85 percent completion. "Skinning" of the command module portion of mock-up 9 (Spacecraft handling and transportation) was completed 23 May.

Completion of mock-up 2 (cabin interior arrangement), mock-up 3 (cabin interior arrangement) and mock-up 5 (cabin exterior arrangement) is scheduled for June; construction of the command module portion of complete mock-up 18 and 19 will be initiated.

Manufacturing has issued initial production orders to the honeycomb bond and processing department with fabrication scheduled to begin in June. Honeycomb core headrests for crewman couches in boilerplate articles will be assembled.

Also scheduled for fabrication and to be delivered to engineering for the Apollo test requirements program, are cylinder attenuators fabricated from crushable honeycomb.

Tooling progress in support of all command module articles has progressed steadily throughout May.

[redacted]

SERVICE PROPULSION SYSTEM

PROPELLANT SYSTEMS

The service propulsion system (SPS) selected is a dual oxidizer, dual-fuel tank arrangement with a simple series transfer system (Figure 1). This system is not interconnected to the reaction control system (RCS); but during zero gravity starts, uses the RCS engines to settle the propellant in the SPS tanks. The single pressurized storage vessel is isolated from the system by dual, normally closed squib valves. Crew operated, normally open solenoid shut-off valves protect the upstream series-parallel regulators. Series-parallel check valves, located between the regulating systems and the propellant tanks, prevent mixing of the hypergolic propellants. A pressure relief valve, vent valve, burst disc, and filter are used between the check valves and propellant tanks.

In the propellant distribution system, a fill receptacle, burst disc, and filter are located downstream of both fuel and oxidizer tank outlets. In the oxidizer system, propellant utilization valves are in parallel. One valve is operated automatically from the tank gauging system; the other is crew operated.

To refine the SPS configuration, design layouts are being continued. The modular concept is being employed wherever practical. Particular design effort will be directed to make complete subsystems more accessible, thus facilitating installation and removal.

Studies of compatibility of elastomeric materials with nitrous tetroxide propellants are under way. Compatibility studies to evaluate 6Al-4V titanium in nitrous tetroxide have been initiated.

The cleaning and purging of construction materials for configuration, systems, and components and of the functional components of the systems are being investigated.

Functional tests of sealing devices have begun.

During the next reporting period, the brazing and disjoining tubing feasibility and reliability tests will be completed; the results of the elastomeric-nitrous tetroxide compatibility studies will be evaluated; and expulsion bladder fabrication will begin.

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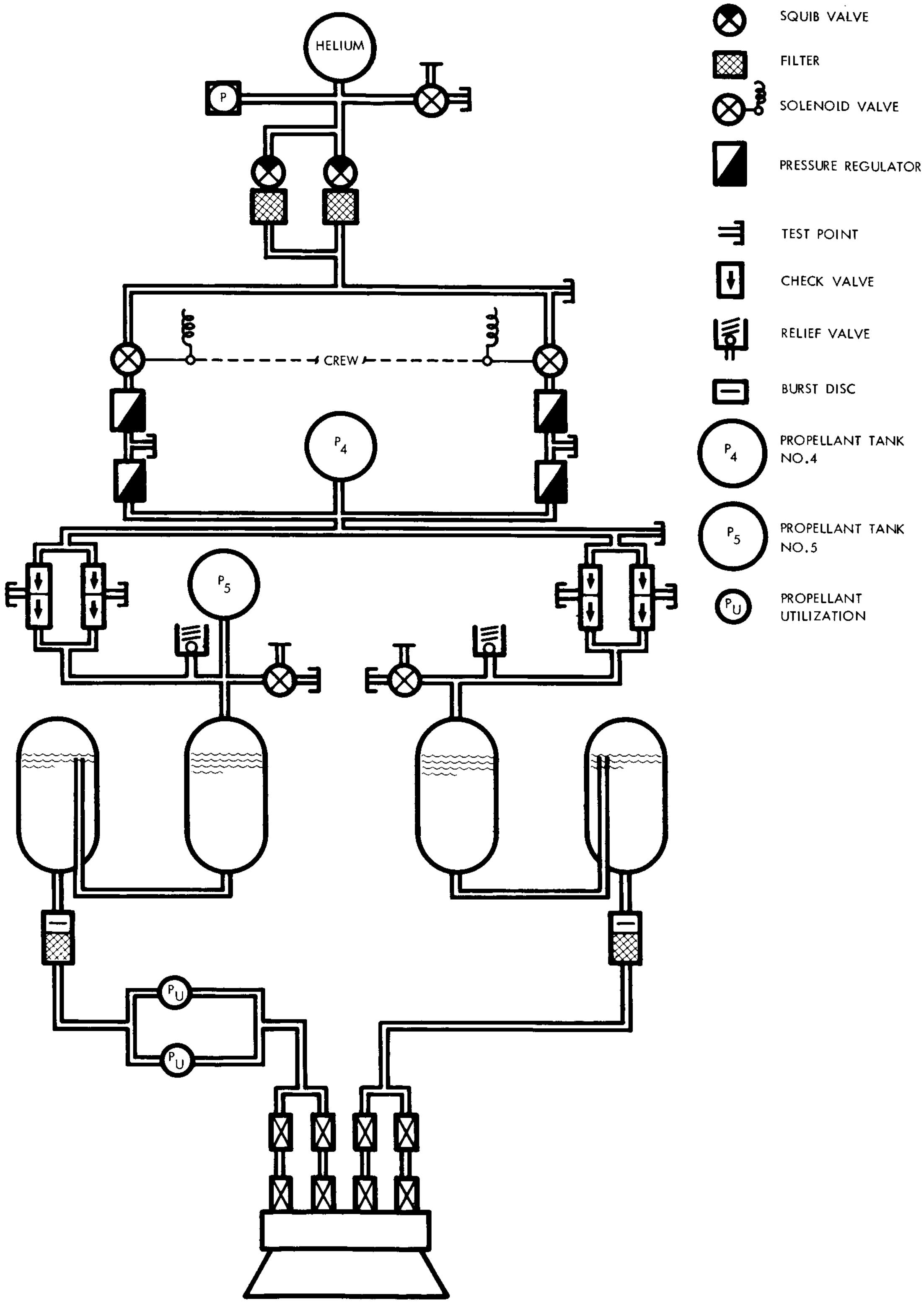

Figure 1. Dual Oxidizer, Dual Fuel Tank With Simple Series Transfer System

ROCKET ENGINE

Specifications

The procurement and documentation specifications are being prepared.

Design

The engine will be designed to attain a three sigma specific impulse of 314 sec.

The nozzle expansion optimization study indicates that when chamber pressure and nozzle area ratio are increased, the vehicle weight decreases.

Hardware

A throat ring-gimbal arrangement is being studied as a means of reducing the required engine gimbal angle and of allowing deeper insertion of the engine into the service module. This approach also may lessen gimbal actuator power requirements.

During the next reporting period, engine procurement specifications will be completed; installation design layouts and study of interfaces will continue; layout studies to support engine optimization study will be prepared; gimbal configuration will be established; and the type of actuator system selected.

TEST

Test plans are currently being prepared to reflect engine reliability and tolerance to off-design conditions.

For the preliminary flight rating test (PFRT), spacecraft layouts are being modified to accommodate off-the-shelf components. A search is being conducted for components closely simulating flight-type equipment that are compatible with the hypergolic propellants used on the spacecraft.

During the next reporting period, test plans will be expanded to include off-design considerations; and plans of simulated altitude test program will be detailed.

SUBCONTRACTOR RELATIONS

S&ID and Aerojet-General Corporation entered a letter contract for the service propulsion rocket engine. A definitive contract is scheduled for 1 August 1962.

Aerojet delivered a soft mock-up of the engine on 19 May 1962.

SERVICE MODULE STRUCTURE AND SUBSYSTEM INSTALLATION

EVALUATORS

A 21,500 engine will be installed on the complete service module evaluator (mock-up 7) rather than the 20,000 engine as planned. The 21,500 engine is 17 inches longer than 20,000 engine, but a change in the engine gimbal point held the installed length increase to 8 inches. The reaction control motors will be installed on top of the service module as modular units rather than as a separate system.

Fabrication of evaluator 4 (service module and adapter interface) continued.

BOILERPLATES

Boilerplate 9, 13, and 15 will include an access door. Boilerplate 13 and 15 will include the separation system between the modules.

No structural provisions will be made for a VHF antenna in boilerplate 9. However, boilerplate 9 incorporates the following prototype design concepts: slant wall crew compartment, main hatch redesign and 3-inch lateral displacement of the aft heat shield.

Drawings of structural details and assemblies have been completed.

CONFIGURATION

The service module length is now 166 inches. This configuration is 42 inches longer than the original length. The change was necessitated because of an increase in propellant requirements. The main propellant tanks and the adapter are also being resized.

STRUCTURE

Primary

Radial beam loads have been reduced approximately 50 percent. These beams will be made by the numerical control method.

The aft bulkhead drawings have been revised to eliminate the carry-through of the radial beam attach structure. Aluminum face sheets will be used for these members as well as for the test panels of the honeycomb junction.

Tanks

The main propellant oxidizer and fuel tanks have been redesigned for an operating pressure of 221 psi with a maximum pressure of 240 psi. These figures result in a 10 percent weight increase.

Tank drawings are being revised to volumes compatible with the new requirement of 39,500 pounds of propellant.

Layouts revising the helium tank trunion mounts are being prepared.

The helium tank has been designed for a burst factor of 2.0. The main propellant tanks have been designed for a 1.5 burst factor.

Requirements for water storage have been reduced. A single tank will be positioned in the location previously used by the dual tanks.

ENVIRONMENTAL CONTROL SYSTEM AND ELECTRIC SYSTEMS

Studies of configuration and of methods of installing insulation in equipment bays were initiated. Fuel cell mounting information is being generated.

SEPARATION SYSTEMS

A study of the major load paths of the command module-to-service module resulted in a 60 percent reduction in the shear load imposed on the command module. This result necessitated a redesign of the tension tie arm; however, only minor revisions of the escape tower toggle latch are required.

A space envelope has been evolved for the ballistic thruster; and the electrical and environmental umbilical envelope was revised.

Design layouts of the service module-to-adapter are nearing completion.

ANTENNA AND RADIATOR DEPLOYMENT

Basic design parameters of the antenna deployment, radiator door deployment, and latching are radically affected by changing to the lunar

[redacted]

excursion module concept. The following design parameter changes are being considered:

1. Radar antenna will not be required on the service module. Deep space instrumentation facility (communication) parabola only will be required.

2. Only one antenna will be required.

3. Antenna will weigh less.

4. Service module radiators will be permanently installed.

5. Service module will be longer.

Sketches conforming to the above requirement are being made. Layout studies of antenna deployment, radiator door deployment, and door latching are in progress.

REACTION CONTROL ENGINES

Five studies of reaction control engine configuration and placement have been completed and are being evaluated by weight trade-off studies. A concept, a "plug-in" reaction control system package, is under study.

LAUNCH PAD

The relation of the command module to the launch complex was rotated 180 degrees from the former position. The service module reference was changed accordingly, and tower umbilical connections were relocated.

Servicing connections, launch complex umbilical connections, and gantry service drawings were completed.

All preflight checks, fueling and pressurization, cryogenics filling, and a count-down sequence were established.

TESTS

Detailed test requirements have been written on the following systems:

Command module - service module separation
Escape tower - command module separation
Service module - adapter separation
Forward compartment heat shield release
Aft compartment heat shield release

Tests conducted on the pyrotechnic cable cutter separation device indicated the cutters cleanly severed 5/32-inch stainless steel cables. No damage or erosion was noted on the cutter chamber bore. The tests also disclosed that the squib fired with only one of its two bridge wires energized.

HARDWARE

A plan of action has been drawn up covering the engineering development laboratory effort necessary to develop lubricants and bearing materials for the Apollo vehicle.

Several display models, approximately one foot square, of the service module radiator panels were made. Fabrication of bonded flanged test sections, typical of radiator panel edge attachment, is still in progress. Photographic coverage of the processing sequences was obtained during the fabrication of these radiator panels and edge attachment test sections.

During the next report period, test specimens of radiator panel edge attachments will be completed, and further evaluation of pyrotechnic devices will be made.

ELECTRICAL POWER SYSTEM

POWER DISTRIBUTION

A major revision to the load analysis is in progress. It will reflect the redistribution of a-c and d-c power. This action resulted from a design decision to generate 400-cps, 3-phase a-c power within the power system. No more than two types of inverters will then be operating at one time, thereby reducing radio noise interference to a minimum. The 800-cps power required will be provided within the guidance system.

A study has been initiated concerning power factor correction and filtering requirements of the inverter. The study of battery characteristics has progressed to the testing stage on AgZn batteries.

During the next report period, the battery charger specification will be completed; testing of inverters and batteries will be completed; and the data will be reduced. The power factor correction study will be completed. Specifications for components of the power distribution systems will be initiated.

SEQUENCER

Functional sequence diagrams have been developed for pad abort, Little Joe II, SA 5, 6, 9 and 10 operations. Design of the sequencer for boilerplate 6 has been initiated. A list of in-flight command functions (radio and hardwire) to be monitored or controlled on boilerplate 6 has been compiled.

During the next report period, schematic diagrams for pad abort, Little Joe II, and SA 5 operations will be developed; and initial design of SA 5 system will be completed.

PYROTECHNICS

An evaluation of hot wire versus exploding bridge wire (EBW) initiation was completed. Categorizing of functions related to range safety requirements and crew safety was completed. All category "A" items and those "B" items not affecting crew safety may utilize hot wire.

During the next report period, all specifications will be completed and released, and design of pyrotechnic circuitry for pad abort, Little Joe II, and SA 5 will be completed.

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EARTH LANDING SYSTEM

A schematic diagram of the system was prepared complying with the decisions to use EBW pyrotechnic devices and to place greater reliability on the crew to operate such function as back-up drogues and parachute bridle release. Emergency crew control was provided for all functions.

Because of early flight test dates of boilerplate 6, 12, 20, and 21, it will not be possible to use prototype equipment that requires development to meet ultimate vehicle requirements; therefore it will be necessary to utilize present equipment in these early vehicles. This applies particularly to EBW's, initiators, and launch escape systems for boilerplate 6, 12, 20, and 21 which have been submitted to S&ID for evaluation. Wherever possible, components used for the test will be used on the prototype vehicles.

RECOVERY AIDS BOILERPLATE 8

Specification SID 62-212 (Recovery Aids Test Article 8) is being rewritten.

LIGHTING

Aged Sylvania fluorescent lamps and Day Ray dimming ballasts were tested to determine relative light intensity versus temperatures from -10 to 200 F and to study operational characteristics in environmental chamber tests, particularly at low temperatures.

Lighting system test fixtures for the area and main display panels are being designed for mock-up studies.

During the next report period, vacuum chamber tests will be initiated to determine lamp temperature versus various ground plan heat sinks.

Work is in progress to design a fluorescent lamp fixture with the determination of the characteristics of manual dimming and maximum heat dissipation to structure.

Vibration and radio interference tests of fluorescent lamps are in progress. The effect of lamps on the primary buss will be monitored.

WIRING AND CABLES

A layout of the escape tower conduit was completed. Fuel cell system plumbing flow schematics and layouts are in progress. A new layout of the service module wire bundle runs in accordance with the latest system locations and structure changes has been initiated.

[redacted]

A schematic of the electrical power system was completed.

The investigation of available wire for use on boilerplate vehicles was completed, and it has been recommended that MIL-W-27300 wire be used for this phase of the program.

Due to the increase in depth required by the in-flight test system, it will be necessary to determine the volume required for the electrical power control of systems in the right-hand spare parts bay.

S&ID will consider using the volume of the right-hand forward equipment bay previously allotted for subsystem control.

FUEL CELL

Fuel Cell Manifold

Analysis indicated that a single manifold for each fuel cell reactant will be sufficiently reliable for the Apollo mission; therefore, redundant fuel cell reactant manifolds will not be required.

The schematic for the fuel cell showing nitrogen, hydrogen, oxygen, and glycol flow has been completed; and the system installation within the service module has been initiated.

A preliminary sizing was done on a 1000-watt fuel cell for use in the small lunar landing module.

Fuel Cell Radiators

An evaluation was made on the possibility of integrating the fuel cell and environmental control system (ECS) heat rejection into one system. Since the integrated system turned out to be 300 pounds heavier and considerably more complex than the two separate systems, the integrated system cannot be used. This increase in weight and complexity was caused by the requirements for subsolar operation. A preliminary design of separate fuel cell radiators has, therefore, been initiated.

Effort was initiated to locate the fuel cell radiators on the service module. The effect of the reaction control motor exhaust products on the radiator surface finish is also being investigated. A study was initiated into the requirements for tying the two systems together in order to establish a lunar night landing capability. A preliminary specification establishing requirements for fuel cell radiators is also being written.

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During the next report period, a document will be prepared specifying the items to be tested in flight. This list will be useful to those groups which are responsible for installation and in-flight displays. The specification on separate fuel cell radiator will be completed. Fuel cell radiator design will be continued. Fuel cell system installation design will be continued.

SUBCONTRACTOR RELATIONS

At a meeting held at S&ID with Pratt & Whitney personnel, new cost estimates prepared for Apollo materials were discussed.

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REACTION CONTROL

PROPELLANT SYSTEMS

Command Module

The reaction control system (RCS) selected is a dual system that is not interconnected (Figure 2). Either system can complete the entire mission. Each system uses a single helium storage vessel isolated by a normally closed squib valve.

A crew-operated, normally open, solenoid shut-off valve gives upstream protection to the two regulators which are used in series. Series check valves are used to prevent mixing of the hypergolic propellants should the positive expulsion device, which separates the propellants from the pressurant, fail. A relief valve and vent valve are used between the check valves and the propellant tanks. A fill-receptacle, burst-disc, filter, and solenoid shut-off valve (normally open) are used in the propellant distribution system.

Service Module

The RCS selected is a quadruple arrangement that has a considerable weight advantage over the dual system (Figure 3). The basic system concept is similar to the command module RCS system except that squib valves and burst discs are eliminated. All the components and propellant tankage will be subjected to system pressures throughout the entire mission, since the service module RCS may have to perform shortly after launch.

A study of the effects of scarfed-nozzle extension of the command module has been initiated.

PROPELLANT SYSTEM HARDWARE

Design, reliability, and test requirements for the helium pressure vessel and positive expulsion tank procurement specifications have been completed.

Specifications for the propellant and helium tank servicing couplings and the explosive-operated helium tank isolation valve will be prepared during the next report period.

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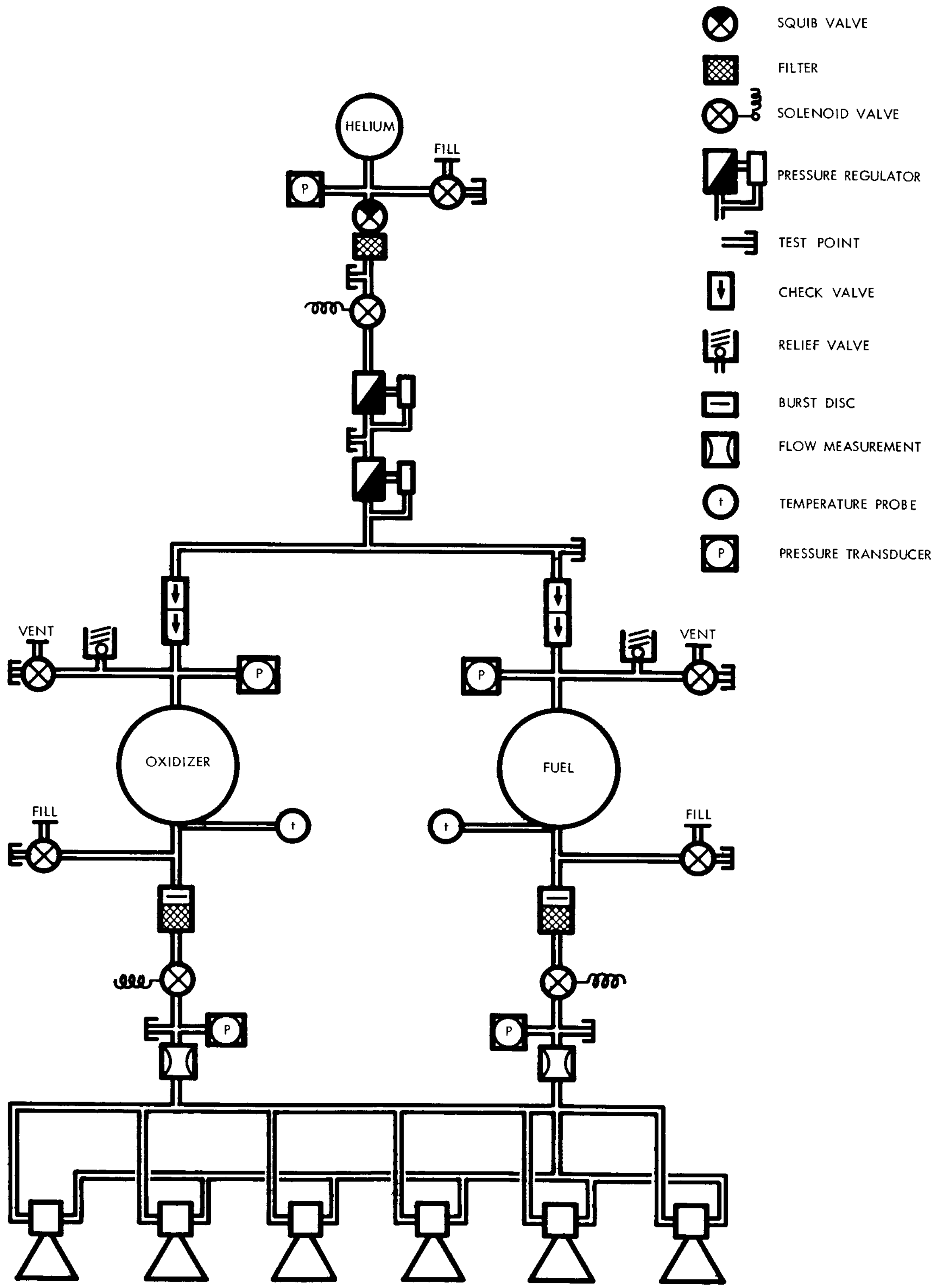

Figure 2. Command Module Dual Systems Not Interconnected

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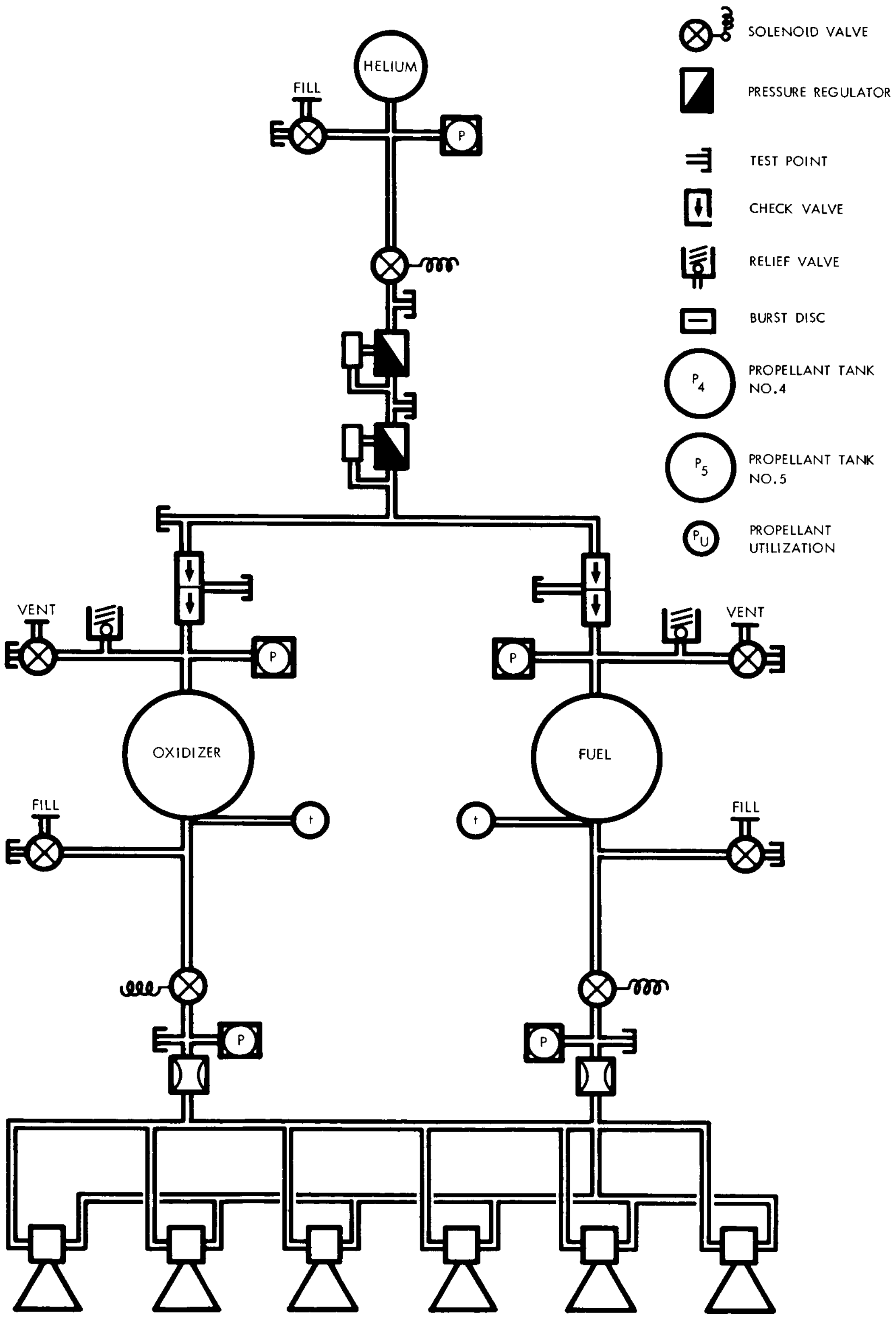

Figure 3. Service Module Quadruple Arrangement

PROPELLANT SYSTEMS TESTING

Command Module

Fabrication of the breadboard test stand continues on schedule. The test stand frame is 100 percent complete; the reaction control equipment compartment is 25 percent complete.

A cleaning and decontamination procedure for component evaluation and breadboard testing has been completed.

The safe handling and storing of the hypergolic propellants was investigated.

A document is being prepared that will be used to train laboratory testing personnel in safe handling of the storable propellants during component and breadboard testing.

Suppliers capable of providing off-the-shelf components for the first phase of the breadboard test program were contacted.

Service Module

A preliminary test plan has been prepared, and test stand design studies are in progress.

Fabrication of the breadboard test stand will be initiated. Procurement of off-the-shelf components to be used during the first phase of the breadboard test program will be initiated.

The breadboard test plan will be formally released, and test procedures will be finalized.

Facilities

Major efforts centered on the establishment of a reaction-control development facility at Downey. The use of hazardous propellants for compatibility studies on materials was also studied. Equipment specifications have been prepared.

Final design of the reaction-control development facility will be initiated during the next reporting period. Effort toward the acquisition of equipment will continue.

ROCKET ENGINE

Mock-up and Boilerplate

S&ID completed fabrication of the first set of command and service module reaction control engines for mock-up. The command module engines have been installed in mock-up 5, and the plumbing installation has been initiated.

Test hardware was fabricated, and a development test program was begun.

Tests conducted include: the flow and cycle of the propellant valves, vortex and doublet injector studies, and sea-level and altitude firings of 100-lb radiation cooled engines.

Reentry Heating

S&ID research indicates a possible thermal decomposition of coolant fuel resulting from extended periods of nonoperation in cold-wall refractory engines. Decomposition prevention measures appear heavier, more complex, and less reliable; therefore, several other cooling methods were investigated. Ablative chambers presented the following advantages:

1. Chamber cooling is inherent in ablator design.

2. The system is not made more complex.

3. Fuel decomposition is minimized.

4. System weight is not jeopardized.

5. Crew preventive action is eliminated.

During the next reporting period, the service module engine thrust level, which is limited by maximum roll torque requirements and minimum impulse required for navigational tracking, will be studied. Test requirements for evaluation of service module RCS engine operation and plume effect on service module radiators will be defined. A study to determine suitability of a hot-firing checkout of RCS systems on the launch pad will be completed. S&ID and Minneapolis-Honeywell will continue studies to establish the electronic driving circuit for the reaction control engine solenoid valves.

SPACECRAFT ADAPTER DESIGN, FABRICATION, AND ASSEMBLY

MOCK-UP AND BOILERPLATE

Fabrication of the adapter for mock-up 9 (handling and transportation equipment) was initiated.

All adapter detail structure drawings for boilerplate 9, 13, and 15 (test vehicle) have been released. The structure assembly drawing has been completed.

STRUCTURE

The basic adapter structure consists of six aluminum honeycomb panels, six longerons, and a forward and an aft bulkhead. Design of honeycomb panels for the Apollo test requirements program has been completed.

The adapter configuration has been revised to incorporate an air-conditioning barrier between the adapter and the instrument unit. A new aft ring-attach bolt circle diameter is made to coincide with Marshall Space Flight Center drawing 10 MO 3064.

SPACECRAFT GROUND SUPPORT EQUIPMENT

GSE CONCEPTS

A preliminary report defining the GSE checkout concept for the Apollo spacecraft has been completed for presentation to NASA. This report provides the basis for the detailed development of the Apollo checkout system.

An Apollo performance interface specification was revised and brought up to date.

The preliminary issue of the GSE requirements and utilization report was released for review. The review is intended to establish more quantity and utilization requirements.

Major subcontractor meetings were held in order to review the GSE concepts, proposals, and specifications.

DESIGN

The preliminary launch escape system schematics for boilerplate 6 and 20 were completed, and the preliminary GSE checkout requirements were established.

Boilerplate 6 procurement specifications for the launch control van, pad abort inter-communications, maintenance van, and telemetry van have been completed. During the next report period, a plan will be developed for the GSE test program which will encompass the in-house verification of the checkout system performance. The plan will define test objectives, configurations requirements, and special test requirements. The development of the major subsystem of the Apollo checkout system will be initiated.

GSE requirements and utilization will be revised to incorporate correction in quantities and use.

GROUND OPERATIONAL SUPPORT SYSTEM

Effort has been concentrated on the determination of requirements for the revision of the ground operational support system (GOSS) specification. Additional material and revisions of the specification contents are being prepared. NASA recommendations for the revision of the GOSS equipment specification were obtained and will be confirmed by a formal letter from NASA. New schedules for both specifications will be included in the letter.

A development plan has been jointly prepared by the GOSS unit and the systems integration group. This plan describes the functions and information flow within the GOSS unit.

A trip was made by GOSS representatives to observe Project Mercury simulation exercises at Point Arguello, California. The experiences obtained during this trip provided a better understanding of problems encountered with remote station operations, equipment, and organization.

During the next report period, revision of the GOSS system specification will be continued; an investigation of ground communications reliability will be accentuated; a discussion of Mercury communications with NASA communication specialists will be scheduled.

FACILITIES

PROGRAM MANAGEMENT AND ENGINEERING AREAS

Program management, engineering, and other Apollo functional division areas have increased from 95,000 to 100,000 square feet during the reporting period.

Apollo associate contractor relations, quality control, and Apollo facilities have been moved into Zone 15 as a part of the plan to consolidate Apollo program management functions.

Expansion of the engineering area is being planned. Apollo logistics will be relocated from Building 6 to Building 1.

MANUFACTURING AREAS

The test panel area has been established; the majority of the equipment has been ordered, and manufacturing will begin work in the area about 15 June.

Boilerplate structural assembly and final assembly layouts were completed, and facilities design of utilities and installations has been initiated.

Training equipment fabrication is planned to be located in Building 43 in Compton. The layout of this area will be complete before 1 June 1962.

All material handling requirements and cost estimates have been completed for inclusion in the cost proposal.

The bonding and test building layout has been completely revised to reflect the latest program changes.

The facilities portion of the manufacturing plan was completed during the month.

The job order for the two welders for boilerplate fabrication was released to purchasing.

Facility construction in Building 43, Compton, will begin in June, 1962, for the trainer fabrication group.

The mock-up fabrication group will be relocated to their permanent location.

Installation of tooling equipment and installation of the overhead crane facilities for boilerplate fabrication will be initiated.

ENGINEERING SUPPORT AREAS

Lack of a definitive test plan has held up decisions regarding both area assignment and equipment requirements. Effort was expended on analysis and investigation to arrive at the necessary decisions. Some problems have been solved, but a major part of the laboratory test plan has not been definitized.

A definitive test plan is expected early in June, 1962. This will allow decisions in regard to equipment, area, and facilities. Apollo plant engineering will continue to define Apollo facilities requirements to support an overall laboratory plan.

FACILITIES PROJECTS

Apollo Engineering design criteria for the following facilities have been reviewed with NASA facilities, and verbal approval has been received subject to minor changes by mutual agreement:

1. Plaster master
2. Systems integration and checkout
3. Bonding and test
4. Impact test
5. Radiographic
6. Parking
7. Building 6 modifications

Apollo Engineering design proposals have been requested for all of the above facilities except Building 6 modifications. Apollo engineering contracts will be awarded as soon as funding approval is obtained. Design will commence immediately after contract award. Facilities Appendix "A", Volume II for Downey plant facilities has been completed and submitted to NASA.

Apollo engineering design criteria for the remainder of the Downey facility requirements are being prepared for submittal early in June, 1962.

The Appendix "A" for the propulsion test facility will be submitted after a site location decision is received.

Investigation and analysis is continuing for the reaction control test facility and space systems development facility.

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APPENDIX

Table A-1. Meetings, May 1962

Subject	Location	Date	S&ID Representative	Organization
Rundown on communication and instrumentation systems	Houston, Texas	2 May	Pope Albinger	S&ID, NASA
Guidance/control interface meeting	Cambridge, Mass	3, 4 May	Antletz	S&ID, MIT
Ordnance item installation requirements of launch complex	Huntsville, Ala	3 May	White	S&ID, NASA
	Huntsville, Ala	3 May		S&ID, NASA
Propulsion, fuel cell, and environmental control systems discussion	Downey, Calif	3 - 4 May		S&ID, NASA
	Cambridge, Mass	4 - 5 May	Jones	S&ID, MIT
Nuclear Radiation shielding discussion	Houston, Texas	5 - 9 May	Clark	S&ID, NASA
Apollo wind tunnel test coordination	Langley AFB	5 - 6 May	Pape	S&ID, NASA
Flight Controller Simulation/GOSS network checkout (Mercury)	AMR	6 - 12 May	Ackerman McCoy	S&ID, NASA
Guidance and control reliability coordination	Houston, Texas	6 - 11 May	Crowder	S&ID, NASA
Test site location survey	White Sands, New Mexico	6 - 8 May	Harvey	S&ID, NASA
Discussion of "O" g propellant feed systems	Cleveland, Ohio	7 - 8 May	Gibb	S&ID, Lewis Research Laboratories
GSE coordination: navigation and guidance system	Cambridge, Mass	7 - 11 May	Allen Morland Hirahara	S&ID, MIT, NASA
Mission reliability and flight Safety requirements meeting	Houston, Texas	7 - 11 May	Henley Campbell Walker	S&ID, NASA
Systems design review meeting	Houston, Texas	7 - 9 May	Brewer Hair	S&ID, NASA
Flight controller simulation exercises	Houston, Texas	7 - 11 May	Ackerman Gore McCoy	S&ID, NASA
Discussion of Apollo guidance system reliability	Downey, Calif	8 May	Hurkowitz	S&ID, NASA
Make-or-buy meeting; Telemetry	Downey, Calif	8 May	Paup	Collins, S&ID
Crew Systems Meeting	Houston, Texas	8 May	Feltz	S&ID, NASA
Design Coordination Meeting	Sacramento, Calif	8 - 9 May	Lewin Mower	S&ID, Aerojet-General
Nuclear radiation shielding discussion	Houston, Texas	8 - 10 May	Clark Pinckney Mayes	S&ID, NASA
Systems analysis, guidance problems, industrial support meeting	Huntsville, Ala	8 - 11 May	Cooper	S&ID, NASA, MIT
Documentation coordination	Langley AFB	9 May	Hunter Eggert	S&ID, NASA

Table A-1. Meetings, May 1962

Subject	Location	Date	S&ID Representative	Organization
Apollo aeroheating test program results	Palo Alto, Calif	9 May	Harthun Lundgren	S&ID, Ames
Apollo Jet effects tests coordination	Hampton, Virginia	9 May	Crowder	S&ID, NASA
Revised parachute design subsystem presentation	Houston, Texas	9 - 10 May	Young Necker	S&ID, NASA
Pad Abort and Little Joe II test discussions	Houston, Texas	9 - 12 May	Pyle Harvey	S&ID, NASA
Wind tunnel tests	Mountain View, California	9 - 12 May	Gillies	S&ID, Ames
Technical coordination and liaison, navigation and guidance system	Cambridge, Mass	10 - 25 May	Martin	S&ID, MIT
Documentation Coordination	Hartford, Conn Wilmington, Mass Minneapolis, Minn Cedar Rapids, Iowa	10 - 15 May	Eggert	S&ID, Pratt & Whitney, Avco Corp., Minneapolis-Honeywell, Collins Radio
Simulation exercises studies and operations (Mercury)	Lompoc, Calif	10 - 15 May	Schepak Koos	S&ID, NASA
Flight controller simulation exercises	Point Arguello Calif	11 - 13 May	Schepak Koos	S&ID, NASA
Coordination; R & D instrumentation systems	Houston, Texas	11 - 27 May	Dunham Raver Barmore	S&ID, NASA
SAWE National Convention	Seattle, Wash.	12 - 18 May	Peters	Symposium
Apollo Electrical System Integration Panel Meeting	Houston, Texas	13 - 16 May	Triman White Dale Champaign	S&ID, NASA
Lunar Landing Simulation Study	Columbus, Ohio Houston, Texas	13 May	Oglevie	S&ID, NASA
Wind Tunnel Tests, Aerodynamics Coordination	Mountain View, Calif	13 - 18 May	Gielow	S&ID, Ames
Flight Technology Technical Panel/ Design Review	Houston, Texas	14 - 15 May	Dudek Schall Bornemann	S&ID, NASA
Stabilization and Control Coordination Meeting, Review; System Design Displays and GSE	Minneapolis, Minn	14 - 27 May	Lu Knobbe Antletz Jensen Watson Rowe Fouts Field Fleck	S&ID, Minneapolis-Honeywell
Apollo Wind Tunnel Coordination Meeting	Houston, Texas	15 - 16 May	Allen	S&ID, NASA
Apollo Propulsion System Briefing	Houston, Texas	15 - 17 May	Simkin	S&ID, NASA
System Fuel Cell Analysis	Houston, Texas	15 - 17 May	Barnett	S&ID, NASA
Propellant Storage Handling Symposium	Cleveland, Ohio	15 - 17 May	Nelson	S&ID, Lewis Research

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Table A-1. Meetings, May 1962

Subject	Location	Date	S&ID Representative	Organization
Life Systems Briefing	Houston, Texas	15 - 16 May	Wells	S&ID, NASA
Staging Interface Problems Discussion	Cleveland, Ohio	15 - 18 May	Hackett	S&ID, Lewis Research
Interface Control Coordination, Configuration Control Meeting	Cambridge, Mass	15 - 18 May	Williamson	S&ID, MIT
Command Module System equipment installation Coordination	Cambridge, Mass	15 - 17 May	Cramer Mayes	S&ID, MIT
Presentation at Society for Experimental Stress Analysis	Dallas, Texas	16 - 18 May	Goldstone	Symposium
Apollo Computer Technical Discussions	Cambridge, Mass	16 - 18 May	Siev Steiner	S&ID, MIT
Mechanical Systems Meeting	Houston, Texas	16 - 17 May	Johnson Necker Stone	S&ID, NASA
National Aero-Space Instrumentation Conference/National Telemetering Conference	Washington, D. C.	19 - 25 May	Zemenick Jones Dorrell Robinson	Symposium
Coordination meeting with MIT, NASA	Houston, Texas	21 - 24 May	Risley	S&ID, NASA, MIT
Discussion of Apollo temporary facilities, material support at AMR	AMR	21 - 23 May	Ford	S&ID, NASA
Plan and Training Meeting	Houston, Texas	22 - 23 May	Pollard Perry	S&ID, NASA
Resident representation	Wilmington, Mass	22 May	Lowery	S&ID, Avco
Training Plan Discussion	Downey, Calif	22 May	Pollard	S&ID, Minneapolis-Honeywell
Guidance and control system meeting	Houston, Texas	24 May	Risley Kennedy	S&ID, NASA
Pad abort and Little Joe II interface Problems	Downey, Calif	25 May	Pearce Cooper	S&ID, NASA, Convair
Subcontractor management office coordination	Wilmington, Mass	25 May	Kerr	S&ID, Avco
Pre-qualifying drop test coordination	El Centro, Calif	28 May	Sanderman	S&ID
Programming Facilities Meeting	Houston, Texas	30 May - 2 June	Flynn	S&ID, NASA, Aerojet General

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